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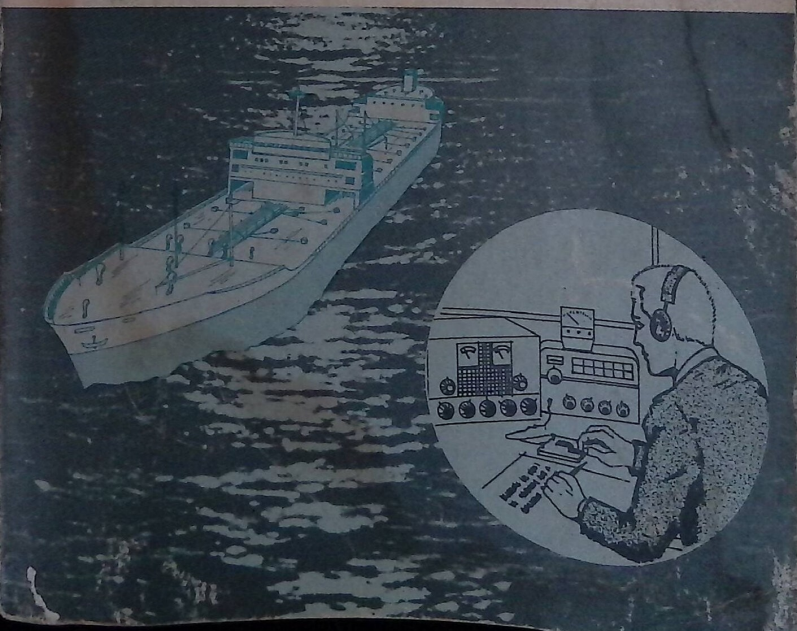
MARINE RADIOTELEGRAPH OPERATOR LICENSE HANDBOOK

by Edward M. Noll



Marine Radiotelegraph Operator License Handbook

by

Edward M. Noll

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Preface

The major objective of *Marine Radiotelegraph Operator License Handbook* is to prepare the prospective license holder for taking the required FCC examinations. A second-class radio-telegraph license requires a passing grade on each of examination elements 1, 2, 5, and 6. Additionally, it is advisable to pass the radar license endorsement examination involving element 8. This book contains the answers to the questions asked in the FCC *Study Guide and Reference Material for Commercial Radio Operator Examinations.* Much additional information is included in introductory chapters. The extensive appendices are of assistance in understanding marine operations and better preparing for the FCC tests.

The first two chapters present details of shipboard radio-telegraph equipment. Subject matter includes radiotelegraph transmitters, shipboard antennas, alarm systems, direction-finding gear, loran, and radar. The answers to the study-guide questions for elements 1 and 2 are given in Chapter 3. Radio-telegraph operating practice, element 5, is presented in Chapter 4. Chapters 5 through 14 cover the more than 700 questions of advanced radio telegraph element 6. These questions have been broken down into specify study areas and arranged for good study continuity.

If you pass the four elements covered to this point (and the prescribed code test), you will obtain a second-class radio-telegraph license. However, Chapter 15 is included to provided a study section for obtaining a radar endorsement on your second-class radiotelegraph license. This endorsement can also be obtained for a first-class radiotelegraph license, a second-class radiotelephone license, or a first-class radiotelephone license.

The handbook concludes with six appendices. These provide pertinent sections of the Communications Act and the FCC Rules and Regulations as well as other helpful operating data.

EDWARD M. NOLL

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CHAPTER 1

Shipboard Radiotelegraph Stations and Operator Licensing

To operate coastal and shipboard radiotelegraph stations, a radio operator must have an appropriate radiotelegraph license. To be navigated on the open sea outside a harbor or port, passenger ships (irrespective of size) and cargo ships of 1600 gross tons and upward must be equipped with a radiotelegraph station complying with appropriate provisions of the Communications Act of 1934. Cargo ships of 300 gross tons and upward but less than 1600 gross tons, unless equipped with a radiotelegraph station complying with the provisions, must be equipped with a radiotelephone station in compliance with the provisions of the Communications Act of 1934.

Operator requirements depend upon whether or not the ship is equipped with an autoalarm. When equipped with an autoalarm, the ship must carry at least one radio officer who holds a radiotelegraph first- or second-class operator license, or a temporary limited radiotelegraph operator license, and who has had at least six months satisfactory service in the aggregate as a qualified radiotelegraph operator in a station on board a ship or ships of the United States. When not fitted with an autoalarm, the ship must carry at least two radio officers, each of whom holds a radiotelegraph first- or second-class operator license, or a temporary limited radiotelegraph radio license. However, the holder of a radiotelegraph first- or second-class operator license or a temporary limited radiotelegraph operator license may not act as a chief radio officer until he has had at least six months satisfactory service in the aggregate as a qualified radiotelegraph operator in a station on board a ship or ships of the United States.

In the case of a passenger ship, the holder of a radiotelegraph second-class operator license or a temporary limited radiotelegraph radio operator license may not act as a chief radio officer. In fact, in accord-

ance with Rules and Regulations of the Federal Communications Commission (FCC), a licensee cannot acquire a first-class radiotelegraph license unless he has one year of appropriate experience.

The purpose of this book is to assist a prospective license holder to obtain a second-class radiotelegraph license. Study the book completely, not just the answers to the study-guide questions. Remember that the study-guide questions are only a guide to preparing for the examination. The actual FCC examinations are in the form of multiple-choice questions. These questions are not released and can be changed at will by the Commission. Nevertheless, if you can answer the study-guide questions and *understand your answers*, you should have no trouble passing the FCC examination. The study of the supplementary information given in this book increases and firms your knowledge of appropriate radiomarine equipment and operating procedures. This additional information is of assistance in helping you pick out the correct answers to some of the more elusive FCC multiple-choice questions.

This first chapter details various licenses and procedural requirements. In addition, a typical shipboard radiotelegraph installation and associated antenna system are described in detail. The second chapter covers radio direction-finding gear. Commercial models are described. The chapter concludes with fundamental discussions of loran and radar direction-finding and obstacle-warning equipment.

Chapters 3 through 15 provide answers to the various study-guide questions. Chapter 3 covers Elements 1 and 2, Chapter 4 covers Element 5, Chapters 5 through 14 cover Element 6, and Chapter 15 covers Element 8. Element 8 need not be passed to obtain a second-class radiotelegraph license; however, passing this element provides a radar endorsement for your license that permits you to work on and operate shipboard radar equipment. The appendices provide much useful information that will help you prepare for the examination and will give you a deeper understanding of compulsory shipboard installations and requirements. Also, much useful operating information is included.

RADIOTELEGRAPH LICENSE CODE AND ELEMENT REQUIREMENTS

The three license classes are first-class radiotelegraph, second-class radiotelegraph, and temporary limited second-class radiotelegraph operator license. Only the holder of a first-class or second-class radiotelegraph operator license may be authorized as a radio officer aboard ship.

Applicants for original licenses are required to pass examinations as follows:

A. Radiotelegraph First-Class Operator License:

1. Ability to transmit and receive spoken messages in English.

2. Transmitting and receiving code test of 25 words per minute plain language and 20 code groups per minute.
3. Written examination elements: 1, 2, 5, and 6.
4. An applicant for a radiotelegraph first-class operator license must be at least 21 years of age at the time the license is issued and must have had an aggregate of one year of satisfactory service as an operator manipulating the key of a manually operated public ship or coast station handling public correspondence by radiotelegraphy.

B. Radiotelegraph Second-Class Operator License:
1. Ability to transmit and receive spoken messages in English.
2. Transmitting and receiving code test of 20 words per minute plain language and 16 code groups per minute.
3. Written examination elements: 1, 2, 5, and 6.
4. If you are licensed as a radiotelegraph second-class operator you may obtain a first-class radiotelegraph license without further examination when you have fulfilled the fourth provision for a first-class radiotelegraph operator license.

C. Temporary Limited Radiotelegraph Second-Class Operator License:
1. Ability to transmit and receive spoken messages in English.
2. Transmitting and receiving code tests of 20 words per minute plain language and 16 code groups per minute.
3. Temporary limited radiotelegraph second-class operator licenses are normally issued for a term of two years.

D. Radar License Endorsement:
1. A holder of a first- or second-class radiotelegraph license or first- or second-class radiotelephone license may obtain a radar endorsement for the license by passing FCC Element 8.

In the code test, the applicant is required to transmit and receive the International Morse code for one minute at the rate of speed prescribed for the particular license grade. In the receiving test, the applicant must receive the Morse code by ear and legibly transcribe consecutive words or code groups without error for a period of one minute of a total of five minutes.

The transmitting test is performed with a conventional Morse key, except that a semiautomatic key, if furnished by the applicant, may be used in transmitting code tests of 25 words per minute. The receiving code test is written in longhand or printed by hand either in ink or pencil, except that in the case of the 25 words per minute code test a typewriter may be used if furnished by the applicant.

Each five characters are counted as one word or code group. Punctuation marks or figures count as two characters.

It is a wise practice to send for the application forms prior to taking the examination. These can be filled out in advance, and, by so doing, you will save time at the examining office. Furthermore, you will receive a schedule of the examination times at the local district office. If you live some distance from a district office, you can ask about the traveling schedule that may bring the examining point near your location. A list of FCC district offices is given at the conclusion of this chapter.

MARINE FREQUENCIES

The main frequency band for ocean going vessels that employ radiotelegraphy is 450-535 kHz. In fact, this is a compulsory band and includes the 500-kHz (600 meter) distress frequency.Types of emission are A1, A2, and A2H. Refer to section 83.105 of the FCC Rules and Regulations given in Appendix II. There is a lower-frequency marine radiotelegraphy band that extends between 90 and 160 kHz. A medium-frequency radiotelegraphy band is between 2065 and 2107 kHz. In addition, there are various high-frequency assignments between 4 MHz and 27.5 MHz as follows:

4.172-4.231 MHz
6.258-6.3455 MHz
8.341-8.4595 MHz
12.503-12.689 MHz
16.660-16.9175 MHz

The five distress frequencies are:

500 kHz —A2 Emission
2182 kHz —A3 or A3H Emission
8364 kHz —A2 Emission
121.5 MHz—A2 Emission
156.8 MHz—F3 Emission

LEARNING THE CODE

There is no shortcut to learning the code. Time and practice are the only way. A suitable way of learning the code for one person may turn out to be an impossible way for another. You must experiment and find the best way for you. However, you will soon learn that attaining the desired speed requires constancy.

If you are a beginner, the first step is to memorize the code and then translate this knowledge into sound. It is the characteristic dot-dash sound of each character that must be impressed on your brain, until sound and letter become synonymous. Listen to code on a scheduled

basis following a day-after-day routine that you will not interrupt. Perseverance is your ally, procrastination, your enemy.

If you are just getting started with the code, radio amateur operation opens a door. Station W1AW, owned and operated by the American Radio Relay League, transmits daily code-practice sessions at various speeds. To obtain a schedule, write to ARRL, Newington, Conn., 06111, or refer to a current issue of their publication, *QST*.

Contact a member of your local amateur radio club to find out if they sponsor a code class for beginners. Sometimes distributors and dealers who handle amateur radio equipment also sponsor code classes, free or at a small charge. Sometimes when you pay a small amount to learn, you do a better job of self-disciplining your activities.

Various code-learning tapes and records are available. These are useful in letting you hear code and in building up your receiving speed. In fact, they are a rather essential part of the learning process. They are particularly useful in studying for the commercial license examinations because they often include five-letter code groups as well as plain English practice.

If you are studying to take the commercial radiotelegraph examination, it is important to have a long-wave and/or short-wave receiver with cw capability (bfo). It is especially desirable to have a receiver with which you can tune in on the 405-535 kHz marine radiotelegraph band. This will give you an opportunity to copy the real professionals. Furthermore, you will learn about basic operating procedures and traffic handling as well. In the beginning, you can tune in on the coast stations which transmit series after series of call letters of the marine mobile stations for which they have messages. After a while, you will learn to tune in on actual radiotelegraph conversations between ships and coastal stations, and occasionally between ships. Other coast stations transmit press, weather, and navigational information. This is an interesting and effective way of learning to copy code if you plan to become a marine radiotelegraph operator.

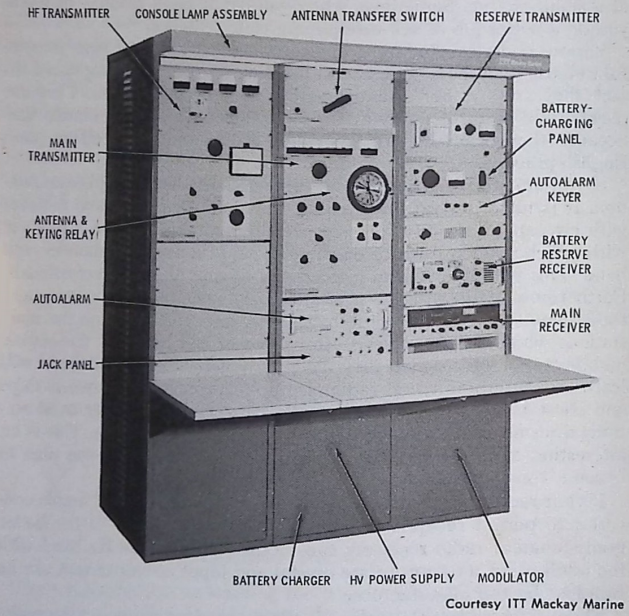
If your receiver is short wave only, you can build a rather simple converter to permit reception of the 500-kHz band. Many of the better grade amateur radio receivers can be used on the 500-kHz band with the addition of an appropriate crystal and input converter that can be supplied by the manufacturer.

There is considerable traffic on the many short-wave marine radiotelegraph bands listed previously. If you will refer to Sections 83.315, 83.316, and 83.317 in Appendix II, you will find some exact frequencies commonly used by ships for calling and working. This information will give you a clue as to where to listen for ship radiotelegraph activities on the various long-wave and short-wave bands. In tuning on these frequencies for code practice, you will also learn how to operate a receiver on the marine bands, which is an invaluable experience you can gain

before your first day in the radio room of a ship. It is an exciting way indeed to build up your code speed after you have mastered the 10 words-per-minute level.

SHIPBOARD CONSOLE

Many shipboard installations are in the form of a complete package including an operating desk. The ITT Mackay Marine radiotelegraph console (Fig. 1-1) is a complete installation including main transmitter



Courtesy ITT Mackay Marine

Fig. 1-1. Shipboard console.

and receiver as well as the reserve battery-operated receiver and transmitter. The main transmitter is housed at the center of the console and includes the antenna and keying relay as well as an approved clock. Note that the two compulsory silent periods are distinctively marked on the clock face.

The main transmitter operates over the 400-535 kHz frequency band and has an output of 500 watts. The A2 modulator for the transmitter is located at the lower right beneath the desk.

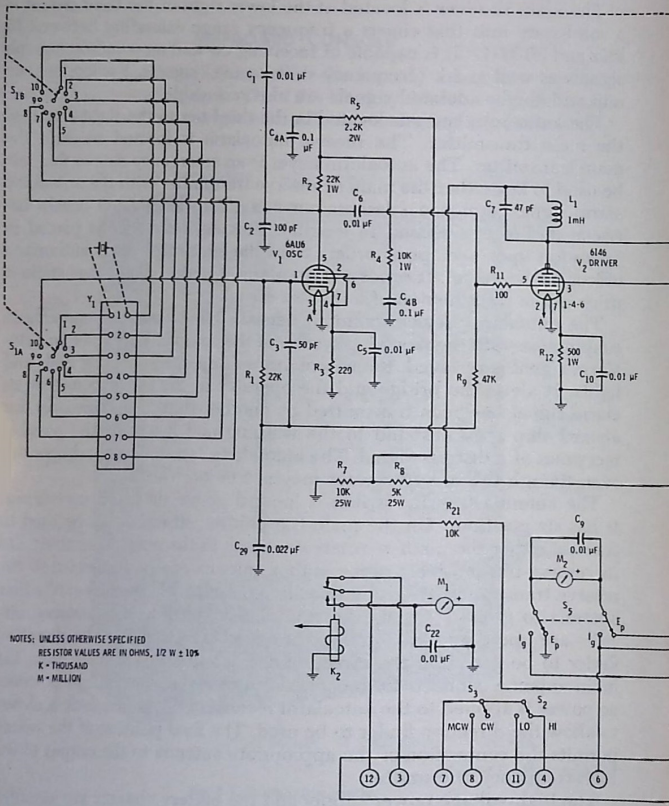
The main receiver is located at the lower right of the third tier. It is a solid-state unit that covers a frequency range extending between 15 kKz and 30 MHz. It is capable of receiving cw and mcw radiotelegraph signals as well as fsk (frequency-shift keying) signals. Radiotelephone a-m and single-sideband signals are also receivable.

The autoalarm keyer is located in the third tier to the right center of the main transmitter. The receive autoalarm is located beneath the main transmitter. The autoalarm keyer is an emergency device that can be used to key either the main or reserve transmitter with the automatic alarm-signal sequence (dashes four seconds in length and breaks between dashes one second in length). This keying device is placed in operation upon receipt of orders from the captain or other authorized officer of the vessel. It sends out an alarm signal to alert other stations prior to the transmission of a distress signal.

The autoalarm device mounted beneath the transmitter operates in conjunction with the receiving system of the console. Whenever an autoalarm signal is received, the autoalarm unit operates warning bells and lights. It alerts the bridge and the operator in the radio room that an alarm signal has been transmitted by another ship. The radio operator aboard ship must respond to the warning and listen for the possible reception of a distress signal. The auto alarm is automatic and operates even though the radio operator may not be on watch.

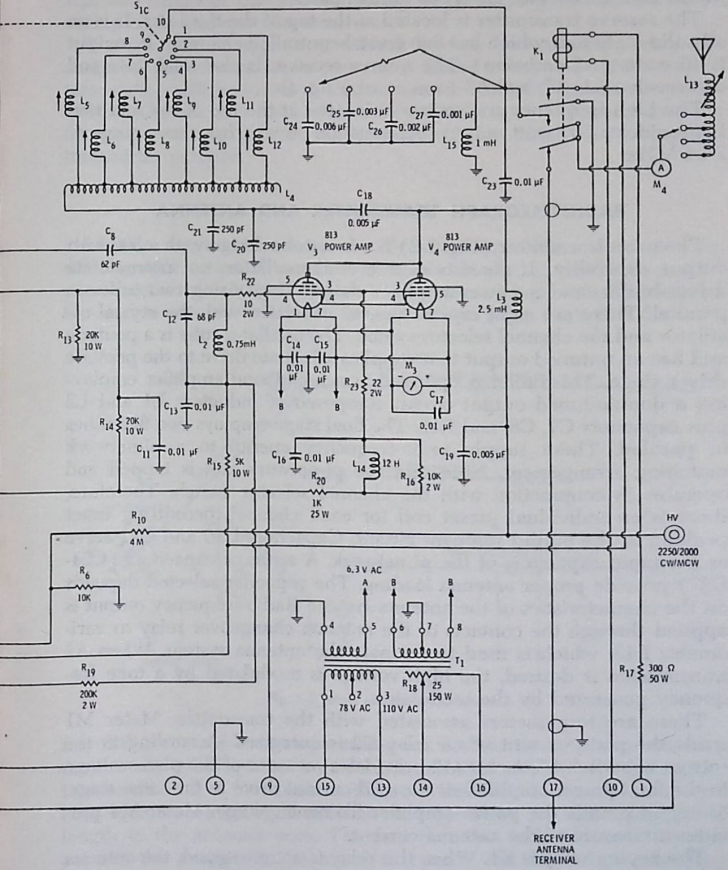
The antenna transfer switch is located above the main transmitter. It has six positions. On the main-transmitter setting, it can be used to connect either the main or reserve antenna to the main transmitter. On its reserve-transmitter position, either antenna can be connected to the reserve transmitter. Its ground position permits the connection of either antenna to ground. On its direction-finder position, both antenna circuits are open, and an interlock is closed which allows the direction finder to be used. On the direction-finder and autoalarm position, the main antenna connects to the autoalarm receiver. Also on this position, ac power is applied to the autoalarm receiver, and an interlock is closed to allow the direction finder to be used. The final position of the switch permits the connection of the appropriate antenna to the output of the high-frequency transmitter.

The high-voltage power supply and the battery charger are mounted in the second tier beneath the desk. The actual battery-charging control panel is positioned to the right of the clock. The battery-charging system permits the 12-volt reserve battery to be charged from the 115-volt ac line. Either the normal maximum charge or the trickle charge rate can be established with the switch on the charging panel. The metering facility permits the battery charge to be monitored. For lead-acid cells,



NOTES: UNLESS OTHERWISE SPECIFIED
RESISTOR VALUES ARE IN OHMS, 1/2 W ± 10%
K - THOUSAND
M - MILLION

Fig. 1-2. Main transmitter



of shipboard installation.

the normal charging rate is 15 amperes, and the trickle charge rate is 200 milliamperes. For nickel-cadmium cells the charge rate is 12 amperes, and the trickle rate is 500 milliamperes.

The reserve transmitter is located at the top of the third tier. It is an all solid-state unit which has five crystal-controlled channels. Its output is 40 watts (A2 emission). The reserve receiver is also solid state and can receive A1, A2, and A3 (a-m or ssb) signals.

The high-frequency transmitter is located at the top of the first tier. It provides a 500-watt output (A1 emission) over a frequency range of 2-24 MHz.

RADIOTELEGRAPH TRANSMITTER AND ANTENNA

The main transmitter (Fig. 1-2) is a four-tube design with a 500-watt output capability. It consists of a crystal oscillator, an intermediate driver-buffer, and a power-amplifier output stage using two tubes in parallel. There are eight crystal sockets associated with the crystal oscillator and the channel selector switch. The oscillator tube is a pentode and has an untuned output that supplies adequate drive to the pentode driver stage. This buffer is operated as a broadband amplifier employing a double-tuned output circuit composed of inductors L1 and L2 plus capacitors C7, C8, and C12. The final stage employs two 813 tubes in parallel. These supply radio-frequency energy to a pi-network matching arrangement. Note that the pi-network coil is tapped and operates in conjunction with the channel selector switch. Therefore, there is an individual preset coil for each channel, permitting exact peaking of the output resonant circuit. Capacitors C20 and C21 serve as the input capacitors of the pi network. A series of capacitors (C24-C27) provide proper antenna loading. The capacitor selected depends on the characteristics of the antenna system. Radio-frequency output is applied through the contacts of the antenna changeover relay to variometer L13, which is used to resonate the antenna system. When A2 transmission is desired, the high voltage is modulated by a tone frequency generated by the modulator.

There are four meters associated with the transmitter. Meter M1 reads the plate current when relay K2 is energized. According to the setting of switch S5, meter M2 provides a measure of the plate voltage to the final power amplifier or the grid-current drive to the same stage. Meter M3 reads the power-amplifier filament voltage. Meter M4 provides a measure of the antenna current.

The keying relay is K1. When this relay is not energized, the antenna is connected to the antenna input of the receiver. In the key-down position, relay K1 is energized and connects the antenna to the output of the transmitter. Another set of contacts shorts out the grid-blocking bias which is connected to the control grids of all three stages of the trans-

mitter when the key is up. Note that this cutoff bias is applied by way of terminal 6 of the terminal board to all four control grids. Resistor R21 and capacitor C29 set the quality of the keying waveform, eliminating clicks and spurious emissions.

The transmitter employs grid-block keying, uses a keying-relay circuit, and provides break-in operation. These terms and other related information will be found in the answers to the FCC questions of element 6. You can refer back to the schematic diagram in Fig. 1-2 and the associated text to gain an understanding of modern radiotelegraph transmitter practice.

ANTENNAS

Three or more antennas are usually associated with a shipboard radiotelegraph station. The main antenna is usually an electrical quarter wavelength in the 500-kHz band. This antenna length usually includes the lead-in wire as well as the flat-top section (Fig. 1-3). For fine tun-

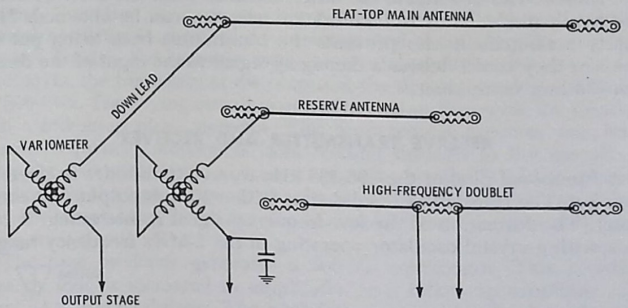


Fig. 1-3. Basic shipboard antennas.

ing of the antenna and compensating for the fact that the antenna wire may not be a full quarter wavelength, a variometer is included at the transmitter end of the antenna. The insertion of inductance at one end of a quarter-wavelength antenna is equivalent to adding physical length to the antenna wire. The fact that this inductance is tunable permits the antenna to be tuned to exactly the desired transmitting frequency.

The shipboard installation also includes a reserve antenna which may not be more than half the length of the main antenna. This, too, can be tuned with a variometer and by additional loading shunt capacitances.

Thus the combination of shunt capacitance and series variometer inductance resonates the shorter antenna to the desired frequency.

If a high-frequency transmitter is incorporated in the console, a third antenna would be a high-frequency half-wave doublet or some other form of antenna that operates efficiently at short-wave frequencies. Occasionally a broadcast receiving antenna and an additional short emergency antenna may be a part of the installation. The latter antenna may occasionally be used for receiving purposes, although in some cases, it can even be loaded by one of the transmitters.

The final antenna (or antennas) is associated with the direction-finding equipment. Such an antenna is usually mounted well away from the other antennas in a clear area where nearby metallic obstacles will not interfere with its directional characteristics. A direction-finding antenna must be calibrated only after the other antennas have been installed in their final mounting positions. Furthermore, the direction finder is usually calibrated when the other antennas are disconnected at the radiotelegraph installation by the antenna transfer switch. Hence, when the directional equipment is used on the bridge, facilities are included to deactivate the other antennas while the measurements are being made. Thus full calibration accuracy can be obtained. This safety arrangement also prevents the transmitters from being put on the air; they could deliver a damaging signal to the input of the direction-finding equipment.

RESERVE TRANSMITTER AND RECEIVER

A functional plan of the 405-535 kHz reserve transmitter is given in Fig. 1-4. The transmitter is solid-state with a 40-watt output (A2 emission). The formation of the low-frequency signal is interesting; it begins with a crystal oscillator operating in the 2-MHz frequency range.

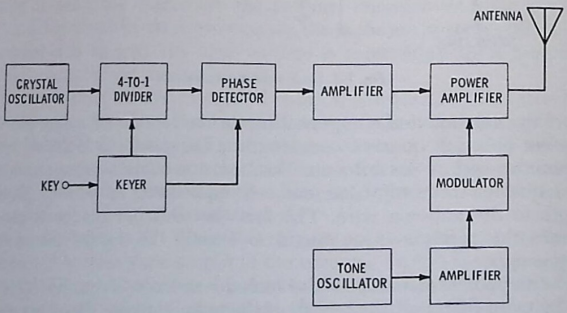


Fig. 1-4. Functional plan of reserve transmitter.

This is in the form of a Butler crystal oscillator using two bipolar transistors (Fig. 1-5). Five separate switchable crystals are employed, permitting five-channel capability. The emitter-to-emitter feedback

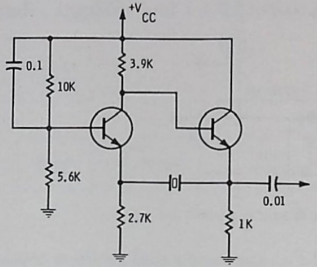


Fig. 1-5. Butler crystal oscillator using npn bipolar transistors.

between two stages provides an easy means of generating stable oscillations. Note that no resonant circuit is required. The output of the crystal oscillator is supplied to an integrated-circuit four-to-one frequency divider. For example, with the crystal-oscillator frequency set on 2 MHz, the frequency at the output of the divider would be 2000/4, or 500 kHz. The keying circuit operates in conjunction with the divider and a follow-up phase detector. This arrangement prevents any harmonic frequency components from feeding through to the amplifier. The phase detector is keyed so as to permit only the 500-kHz component to pass through. Resonant circuits are associated with the amplifier and the power amplifier to develop an amplified and good-quality low-frequency rf sine wave.

The tone oscillator generates a 500-Hz component. This low-frequency tone is increased in amplitude by a follow-up amplifier and applied to the modulator. The modulator output high-level modulates the power amplifier.

The power amplifier (Fig. 1-6) employs three power transistors in parallel. The cw input is applied to the paralleled bases. The collectors are also paralleled and receive the dc component of collector voltage (which has been modulated by the tone frequency) by way of a radio-frequency choke. A T-network matches the low-impedance output of the power transistors to the antenna system. The output circuit includes the antenna rf ammeter and the break-in antenna changeover relay. In the relay position shown, the antenna is connected to the receiver. However, when the key is down, relay K1 is energized, and the relay contacts connect the output of the power amplifier to the antenna through the variometer system. There is a two-position tap on the vari-

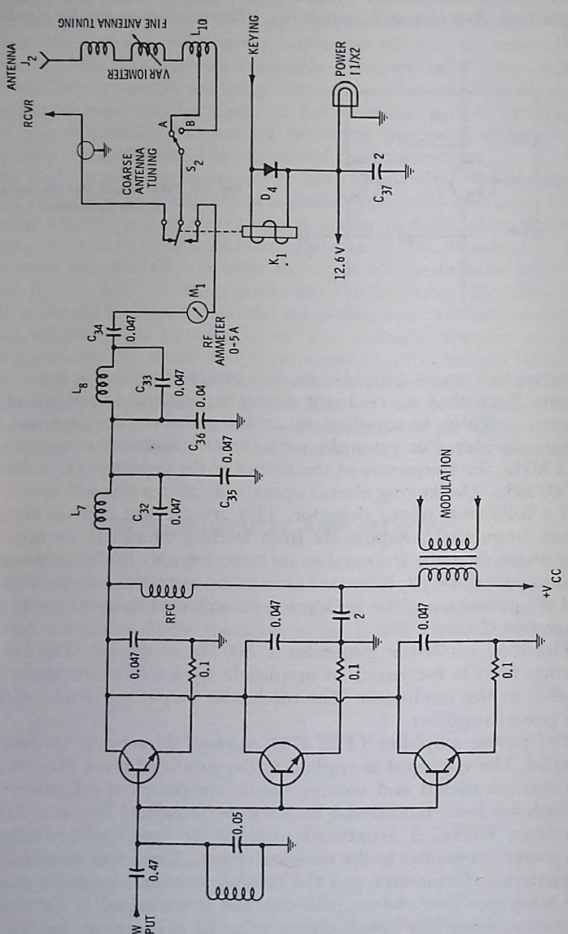


Fig. 1-6. Power-output stage (40 watts).

ometer coil that provides coarse antenna tuning. The variometer itself provides tuning and exact match to the antenna.

The solid-state receiver (Fig. 1-7) employs a regenerative detector. It includes a two-stage rf amplifier, followed by the detector and an audio amplifier and integrated-circuit audio output system. This re-

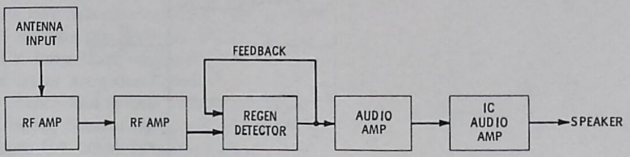


Fig. 1-7. Functional plan of solid-state reserve receiver.

ceiver employs four transistors and two integrated circuits. Its regenerative detector provides high sensitivity and the capability of receiving both A1 and A2 emissions. The receiver operates in four bands as follows: 15-41, 37-105, 95-260, and 240-560 kHz.

The receiver can be operated from the power mains or from the console battery system. As mentioned previously, a battery charger and battery control panel are part of the shipboard console.

The radio-frequency amplifier and detector sections of the receiver (Fig. 1-8) use MOSFET and junction FET transistors. The signal is first applied to a tuned input transformer which is connected to one of the input gates. The second stage employs a tuned output circuit that links the signal to the detector. Radio-frequency gain is controlled with the potentiometer that sets the bias on the second gate of both transistors. Two low-noise and stable high-gain rf stages result. The detector uses a junction FET connected in a regenerative detector circuit. Feedback is supplied to the input circuit from the source by way of a coupling capacitor and the feedback coil. The regeneration control is associated with the source circuit. This control is advanced just slightly beyond the oscillation point for the reception of A1 signals; it is adjusted slightly below this setting for A2 signals. Audio is removed from the drain output circuit by way of an audio transformer.

PORTABLE LIFEBOAT RADIO

Portable distress transmitters and receivers have been designed for operation by untrained persons in lifeboats and life rafts. This emergency equipment is not battery operated but receives its power from a hand-cranked generator. Thus it can be operated continuously and for an indefinite length of time until help is forthcoming.

When the unit is in the automatic mode, one need only turn the

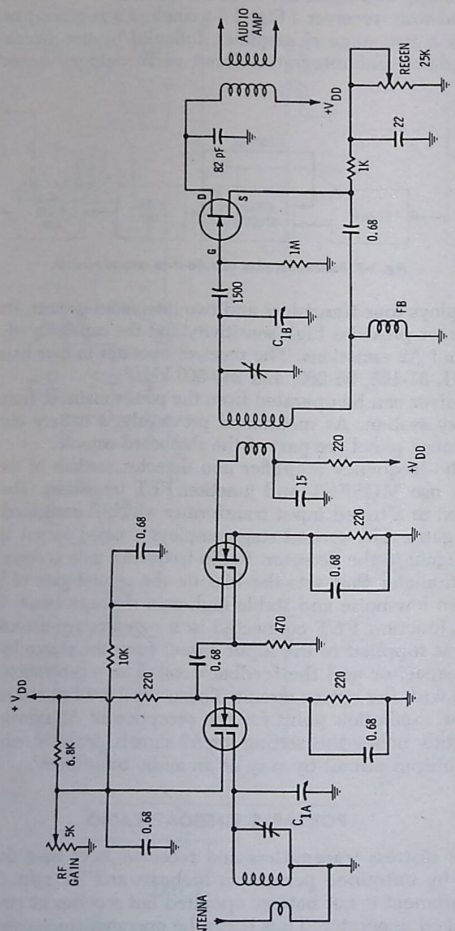


Fig. 1-8. Two-stage FET amplifier and detector.

crank at a speed of 50 to 70 revolutions per minute. The cranking effort amounts to a power of only about 0.10 horsepower. If batteries are available, they can be used to operate the equipment.

Two emergency signals are transmitted. One is sent out on the 500-kHz distress frequency, and the other is transmitted on the short-wave 8.364-MHz emergency frequency. The transmission alternates between these two frequencies—for one minute the automatic autoalarm and SOS signals are sent on 500 kHz, and the next minute the SOS signal and a long thirty-second dash are sent on the 8.364-MHz frequency. The latter long dash permits the radio direction-finding equipment on the search and rescue vessels or aircraft to provide a bearing on the signal being transmitted from the lifeboat. These signals are sent out as long as the crank is turned.

If the radio operator is also aboard the lifeboat, he can adjust the controls so that the unit can be operated manually, and he can establish actual contact with the rescuing craft. A receiver is also a part of the installation.

The total weight of the unit is 56 pounds, including the rope necessary to lower it from the ship to a lifeboat if it has not already been incorporated into the lifeboat structure. Also included are an antenna mast and antenna ground lead, which are collapsible and can be opened up in setting up the transmitter-receiver on the lifeboat. Power output is approximately 1 watt at 500 kHz and 4 watts at 8.364 MHz.

A functional block diagram is given in Fig. 1-9. The transmitter circuit uses a master oscillator and a power amplifier. There are two crys-

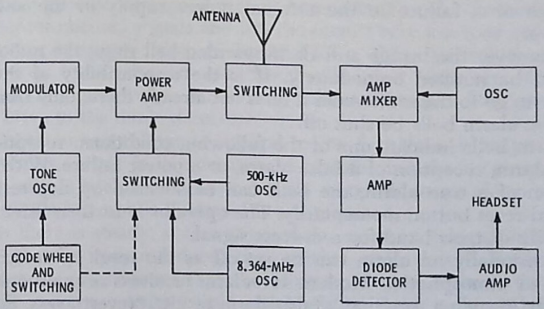


Fig. 1-9. Functional plan of lifeboat radio.

tal oscillators which are switched back and forth at one-minute intervals when the lifeboat radio is set for automatic operation. The oscillator pair is followed by the rf power amplifier. It includes an ingenious resonant output circuit and coupling system that accommodates both

frequencies and applies them to the lifeboat antenna. If manual transmission is desired, the inclusion of a relay permits break-in operation. A tone oscillator provides modulation for A2 emission.

The receiver operates as a tuned-radio-frequency receiver for reception on the 492-508 kHz range. There are two rf stages followed by a diode detector and an audio amplifier. In receiving on the 8.266-8.745 MHz range, the same stages act as a tunable superheterodyne receiver. The associated oscillator is switched on, and the first rf stage acts as a mixer. The incoming high-frequency signal is beat down to an intermediate frequency in the 500-kHz range. In this mode of operation, the second rf stage functions as an i-f amplifier. The diode detector and audio amplifier follow. The code wheel and switching circuit ensure the proper time sequence of switching and also develop the space-mark intervals for sending out the SOS signal as well as the alarm and long-dash direction-finding components.

AUTOALARM RECEIVER

The autoalarm receiver is a part of the radiotelegraph console and can be operated, tested, and adjusted from the operating position. This compulsory piece of equipment monitors the international distress channel (492-508 kHz) automatically while the radio officer is off watch. If it intercepts the international alarm signal, it causes alarm bells to ring in the radio room, on the bridge, and in the radio officer's cabin. The device also sets off the alarm bells when there is a low mains voltage or a failure in the internal power supply of the autoalarm receiver.

Whenever the bridge autoalarm warning bell rings, the radio officer should be notified immediately. It is the responsibility of the radio officer to go to the radio room if he is not already there; only from there can the alarm bells be shut off.

Alarm bells indicate one of the following conditions: reception of a true alarm, reception of a false alarm, or a power failure. With the reception of a true alarm, the bells can be silenced by depressing the normal-reset button momentarily. The operator must then listen on the 500-kHz distress band for a distress signal.

Occasionally an alarm can be set off as the result of interference, static, or atmospherics. Modern autoalarm receivers respond only occasionally in such a way that a false alarm results. Nevertheless, the operator must momentarily depress the normal-reset switch and monitor the distress frequency.

If the alarm bells continue to ring after the normal-reset switch has been depressed momentarily, an equipment failure is indicated. In this condition, the bells can be silenced only by taking the autoalarm off watch until the failure has been corrected.

It is also possible that severe interference in the form of a more or less continuous signal, although it cannot set off the alarm, can reduce the effectiveness of the receiver in being able to respond to an actual alarm signal. Autoalarm receivers also include facilities that indicate improper receiver adjustment or other failures in the equipment. Such a warning light is often installed on the bridge. When this condition exists, the radio officer must make the necessary receiver adjustments to reach an optimum setting for receiving a possible alarm signal under adverse reception conditions. Modern autoalarm receivers include special agc systems that help in maintaining the utmost sensitivity to any received alarm signal while rejecting interference and static as much as possible.

The standard autoalarm signal involves the transmission of four-second pulses with intervening one-second spaces for a period of one minute. Thus twelve pulses are transmitted in a one-minute period. Autoalarm receivers must respond to four successive pulses of this type, setting off the alarm bells.

When an automatic alarm keyer is used, the alarm signal is sent in a precise manner. However, when the alarm signal must be keyed by a radio operator, the timing may not be as exact. Consequently, the autoalarm receivers have certain limits of operation. For example, an ITT Mackay Marine unit responds to pulse durations between 3.5 and 6 seconds and spacings of 0.01 to 1.5 seconds.

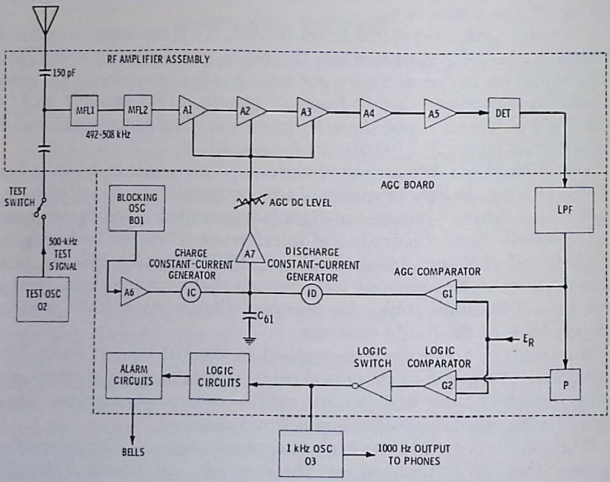
A functional block diagram of the solid-state model is shown in Fig. 1-10B. The input circuit consists of two ceramic filters connected in cascade; these provide passage of signals transmitted in the distress band but reject off-channel signals and interference. There are four cascaded single-tuned rf stages using dual-gate FET's; these permit the autoalarm system to be actuated even though the input autoalarm signal is less than 100 microvolts. An emitter-follower stage (A5) provides proper drive to the diode detector.

Note that an agc voltage is applied to the first three rf stages. This agc system is unique in its operation in maintaining the receiver operating condition such that it most readily responds to an alarm signal. Thus, frequent manual adjustment is not required.

When there is steady, severe atmospheric noise or telegraphic interference, the agc system reduces the receiver gain slowly. It also prevents impulse interference from building up an agc voltage that will lower the receiver sensitivity too much. When there is dense interference, the gain is only reduced slowly until gaps appear in the interference. The sensitivity is restored quickly. Because of this action, an arriving alarm signal can be intercepted. A level setting control sets the agc bias for zero-signal conditions. This bias results from the constant-current pulses placed on capacitor C61 by the output of the blocking oscillator. The agc adds bias to this capacitor when necessary.

Courtesy ITT Mackay Marine

(A) Autoalarm unit.



(B) Functional diagram.

Fig. 1-10. Autoalarm receiver.

In operation, the receiver threshold sensitivity is held above the average noise level, preventing the noise from locking up the succeeding logic circuits.

The 500-kHz test oscillator can be used to check the operation of the autoalarm circuits. When an incoming signal exceeds the receiver

threshold level by 6 dB, the logic comparator operates and drives the logic switch to a 1 level. It is the function of the logic circuits that follow to respond to the time duration for which the logic switch is at 1 and to the duration that it is switched back and held at zero as the incoming signal switches the logic output between 1 and 0, 0 and 1.

When the logic section interprets four correctly timed and correctly spaced pulses, it sets off an alarm system, indicating that a ship may be about to send a distress signal. The logic system must be designed to make an appropriate response to the following conditions: when it has been determined that a dash is too long, when it has been determined that a dash is too short, when it has been determined that a dash is valid, when it has been determined that a space is too long, when it has been determined that a space is too short, and when it has been determined that a space is valid. When valid dashes and spaces occur in the proper sequence, the alarm indicator is activated and a relay system turns on the bells.

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2	NEW YORK, NEW YORK 10014 748 Federal Building 641 Washington Street
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4	BALTIMORE, MARYLAND 21201 819 Federal Building 31 Hopkins Plaza
5	NORFOLK, VIRGINIA 23502 Military Circle 870 North Military Highway
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CHAPTER 2

Direction Finders and Radar

Direction finders aboard modern ships are of two basic types, radio compass and loran. A radio compass operated in the medium-frequency band, 285-320 kHz, has good accuracy up to 100 miles, and useful bearings can be taken in the daytime up to nearly 200 miles. In its nighttime range, it is less reliable beyond 100 miles because of the interaction between the ground wave and sky wave. Under some circumstances, the adverse influence of the nighttime skywave can be felt at distances even less than 100 miles. Nevertheless, the radio compass is very reliable and is used extensively in sailing coastal waters.

High-accuracy, longer-range readings are possible with the LOng RAnge Navigation equipment known as *loran*. The daytime range is 700 miles and greater; nighttime distances can be extended out to more than 1400 miles.

When using a radio compass, the operator takes bearings on radio beacon coastal stations, the exact positions of which are known. Similar coastal stations transmit loran signals in the radio-frequency spectrum just under 2 MHz. The loran receiver on shipboard evaluates the time delay in the reception of various signals from two pairs of loran coastal stations. This information is processed by the loran indicator, and a readout bearing can be obtained.

Radar is used principally as a navigation guide. It is a self-contained system and requires no coastal station. It sends out its own transmission in the form of a microwave pulse. When this pulse strikes a reflecting surface, a return signal is picked up by the radar receiver. By evaluating the time needed for a pulse to go out and come back, and knowing the angle from which the return pulse has come, the radar display is able to determine the distance and direction of obstacles in the path of navigation. In fact, a radar unit displays on an oscilloscope screen a simple relief map that shows the various other ships, obstacles, and

shore outline. It is of definite aid in navigating busy waters near shore and for traveling in fog and other adverse weather, day and night.

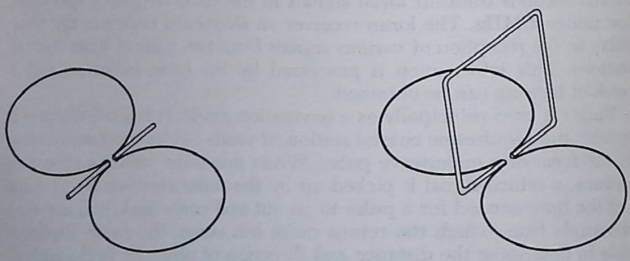
RADIO DIRECTION FINDER

Modern ships use a marine radio compass to determine their positions exactly. The basic principle of direction finding is based on the fact that radio waves travel in a straight line, particularly over water where there are no objects that can distort their passage. If a receiving system can determine the direction of signal arrival, one has a means of obtaining bearings.

A radio or other navigational officer uses his radio compass to obtain an exact bearing on each of three or more shore stations. The operating conditions and locations of the shore stations are known. Once the required bearings have been obtained, a navigation chart can be used to obtain the exact position of the ship relative to the shore stations or in geographic coordinates (degrees of latitude and longitude).

A radio compass requires the use of a directional antenna system. Such a directional antenna system can be in the form of a rotatable loop, or it may be a fixed-position antenna with its directivity changed by a rotating coil assembly or other electronic means.

A half-wave dipole or horizontal Hertz antenna has a figure-eight directional pattern (Fig. 2-1A). This antenna is most sensitive when the plane of the antenna is broadside to the direction of signal arrival. It displays minimum sensitivity, or *nulls*, off the antenna ends. Consequently, as such an antenna is rotated their will be two positions in which it will receive maximum signal and two positions which will be null points. If such an antenna is made into a loop of approximately one wavelength in circumference, it will also display a similar figure-eight pattern (Fig. 2-1B); there will be maxima perpendicular to the plane of the loop and minima in the plane of the loop.



(A) Dipole antenna. (B) Loop antenna.

Fig. 2-1. Figure-eight directional antenna patterns.

A converse situation exists when the size of the loop is made very small in comparison to the wavelength of the received signal. The coastal radio-beacon stations transmit at very low frequencies. Therefore, they have very long wavelengths. A loop approximately 3 feet in diameter consisting of multiple turns of wire has a very short physical dimension in comparison to the wavelength of the radio-beacon signals. Observe the directional characteristics of a small loop in Fig. 2-2. Its sensitivity pattern is also a figure eight. However, the two null points are perpendicular to the plane of the loop, and the maxima occur in the end-on directions.

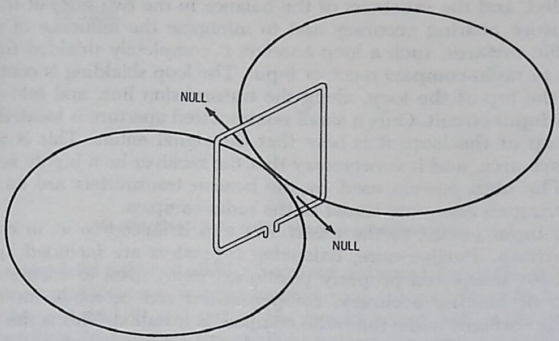
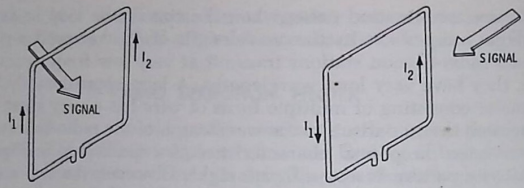


Fig. 2-2. Figure-eight directional pattern of radio compass small loop.

It should be noted that the two null points are sharp and deep and not nearly as broad in angular width as are the two maxima. Thus it is customary in the operation of a radio compass to take bearings within the null positions because a more distinct and accurate reading can be obtained. Since there are two null points, such a directive system is said to be *bilateral.*

The reason for the particular directional pattern of a loop antenna with an electrical diameter that is many times shorter than the wavelength of the received signal is shown in Fig. 2-3. When the loop is in the position shown in Fig. 2-3A, the voltages induced into the sides are equal, resulting in equal currents that have the same direction. The net current is zero. With the loop positioned end-on (Fig. 2-3B), the instantaneous induced voltages are not equal. A differential current is present in the loop, and a signal voltage appears at the output.

The quality and accuracy of the figure-eight pattern of a loop antenna depends on how well the loop is constructed, how well it is



(A) Currents cancel. (B) Currents add.

Fig. 2-3. Directivity of a small loop.

shielded, and the exactness of the balance in the two sides of the loop. To ensure bearing accuracy and to minimize the influence of nearby metallic surfaces, such a loop antenna is completely shielded from antenna to radio-compass receiver input. The loop shielding is continuous from the top of the loop, along the transmission line, and into the receiver input circuit. Only a small noninsulated aperture is located at the very top of the loop; it is here that the signal enters. This is a small entrance area, and it is necessary that the receiver be a highly sensitive one. The high powers used by the beacon transmitters are an aid in delivering an adequate signal to the radio compass.

The input circuit to the receiver is also balanced so as to equalize leg currents. Furthermore, balancing capacitors are included and can be set for sharp and properly positioned nulls. Also, to ensure a high degree of bearing accuracy, compensations can be made for nearby metallic surfaces when the radio compass is installed. This is the reason that the ship radio-station antennas should be in position and the antenna transfer switch set to its bearing-reading position prior to the calibration of the ship's radio direction finder.

UNILATERAL SENSE INDICATION

As mentioned previously, a direction-finding loop has a bilateral pattern. Thus the arriving signal could be from either side of a null setting. Such a loop alone indicates only the line along which the ship is located relative to the transmission point of the received signal (shore station). Usually the operator does know the approximate bearing of the shore station being received, and it is not necessary to take a sense reading. For example, in sailing along the eastern coast, one would know that the shore station would be to the west.

However, there might be situations in which a null-signal position would raise a doubt. For example, is the bearing 80° or 260° in Fig. 2-4? When this situation arises, a vertical *sense* antenna is used along with the loop. The pattern of a vertical antenna is circular, as shown in Fig. 2-5A. The net effect of the vertical and loop antennas is to ob-

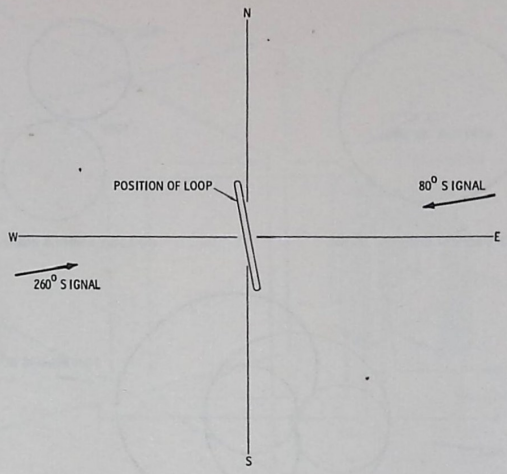


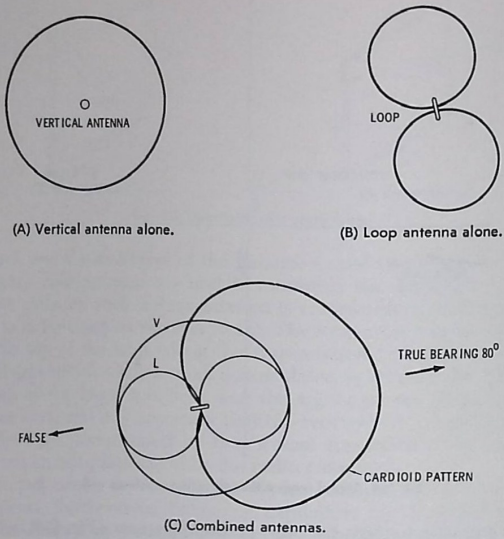
Fig. 2-4. Signal from either direction produces null.

tain a composite pattern called a *cardioid* pattern (Fig. 2-5C). Such a vertical sense antenna is usually located near the direction finder, and it can be switched in and out of the circuit as an aid in obtaining a sense reading. Notice that the cardioid pattern has only one maximum and one minimum.

In taking an actual bearing, the loop antenna is first used alone to obtain a sharp bidirectional minimum. Then the sense antenna can be switched into the circuit and the loop rotated for maximum to determine the sense of the bearing and the true direction of signal arrival. Finally, the sense antenna is switched out, and the loop is readjusted for a null to obtain the exact reading. The use of the sense antenna permits one to select the true bearing rather than the reciprocal one. An exact fix is obtained by taking bearings on two or more beacons and plotting them on a navigation chart.

BELLINI-TOSI RADIO COMPASS

A direction finder can use two fixed antennas instead of a rotatable loop. In such an arrangement (Fig. 2-6), two loops are mounted at right angles to each other. Shielded leads then connect each loop to the corresponding fixed coil of a *goniometer*. Inside of the two fixed coils is a rotatable coil. This coil develops an output voltage that corresponds



(A) Vertical antenna alone.

(B) Loop antenna alone.

(C) Combined antennas.

Fig. 2-5. Use of sense antenna to obtain true bearing.

to the relative signal levels in the two fixed coils. The shaft of the rotor is connected to a calibrated scale.

Actually, the rotating coil is similar to a rotating loop and is used for determining the direction of arrival of received signals. The entire assembly must be shielded and balanced just as the rotatable loop assembly described previously. Balancing capacitors as well as loop-tuning capacitors are included.

Each loop has a figure-eight sensitivity pattern with maximum voltage being induced when the signal arrives in the plane of the loop. If we assume that the signal is arriving in the plane of loop 1, there will be maximum current present in coil 1 of the goniometer. Conversely, with minimum induced voltage in loop 2 there will be minimum current in fixed coil 2. If the rotating coil is now moved in such a manner that its plane is parallel with the plane of coil 1, there will be maximum voltage induced into the rotor. If the rotor is positioned where it is perpendicular to coil 1 and parallel to coil 2, there will be minimum induced voltage.

Assume that the radio wave arrives at a 45° angle relative to both loops. In this case, the amplitudes of the currents in the fixed coils are

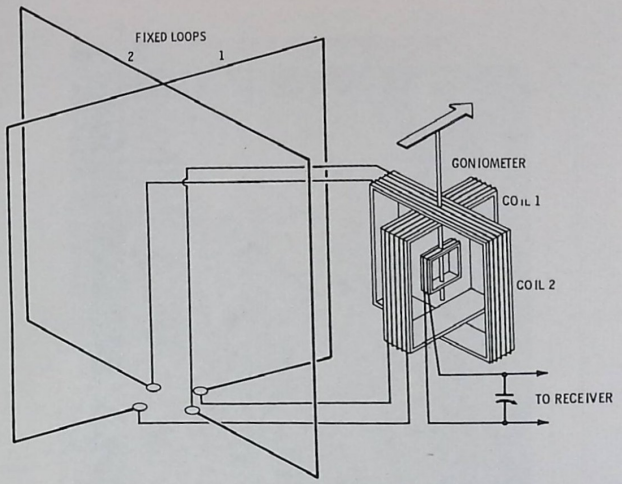


Fig. 2-6. Bellini-Tosi goniometer direction-finder system.

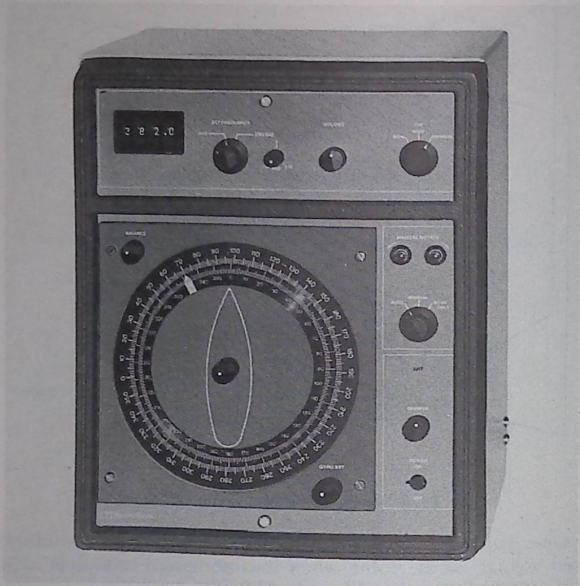
the same. However, the phasing is such that there will be maximum induced voltage in the rotor when it is positioned in a plane midway between the planes of coil 1 and coil 2.

In summary, a complete rotation of the rotor will result in a response that is identical to that obtained by the rotation of a loop antenna, despite the fact that the antenna actually consists of two fixed loops mounted at right angles.

AUTOMATIC DIRECTION FINDER

An advantage of the combination of fixed loop and goniometer is that it is adaptable to automatic direction finding. In such an arrangement, the goniometer rotor is rotated by a servo system. An example of this type of direction finder is the ITT Mackay Marine 4005A (Fig. 2-7). The operator sets the direction-finder receiver on the frequency of the radio beacon to be received. In two seconds, the bearing is indicated automatically. The true bearing is indicated directly on the circular bearing scale if a suitable coupling is made to the ship's gyrocompass. A simple fixed card bearing scale provides a bearing reading that is relative to the ship's heading.

The automatic direction finder (adf) has three operating modes. In the automatic mode, the incoming signals are picked up by the loop



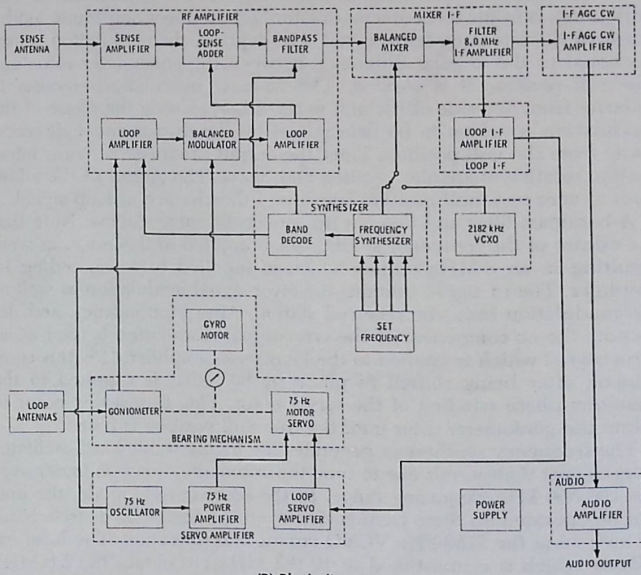
Courtesy ITT Mackay Marine

(A) View of panel.

Fig. 2-7. Automatic

and sense antennas. By suitable combining and processing, the bearing information is displayed automatically. The second mode is receiver only; in this mode the loop-antenna circuits and servo system are disabled. The signal picked up on the sense antenna can be demodulated to obtain audio output information. The third mode is manual; the sense antenna is disconnected, and the receiver picks up a directional signal from the loop antenna. It is now possible to rotate the bearing pointer manually to obtain an aural null after sensing has been determined in the automatic mode. This manual function is used only when heavy noise and interference conditions make it impossible to obtain a precise automatic bearing.

From Fig. 2-7B, note that the goniometer has a mechanical connection to a 75-hertz servo motor. This is the mechanical link to the goniometer rotor. The power for the servo motor and servo system is generated by a solid-state power oscillator. A succeeding power amplifier



(B) Block diagram.

direction finder.

has an output that is applied to the fixed-phase winding of the servo induction motor. The oscillator also supplies a switching voltage to the balanced modulator located in the rf amplifier chain. The servo loop is completed from the loop i-f amplifier to the loop servo amplifier, which supplies the error signal to the servo motor.

The output of the rotary coil of the goniometer is applied to the loop amplifier, the output of which is then applied to the balanced modulator. In the balanced modulator, the rf signal is modulated by the output of the 75-hertz oscillator. In effect, a double-sideband signal with suppressed carrier is formed. This results in the generation of two 75-hertz sidebands. The magnitude of these sidebands depends on the position of the goniometer rotor relative to the level of the loop signals in the two fixed coils of the goniometer. The output of the balanced modulator becomes zero after the goniometer rotor hunts and finds its null position.

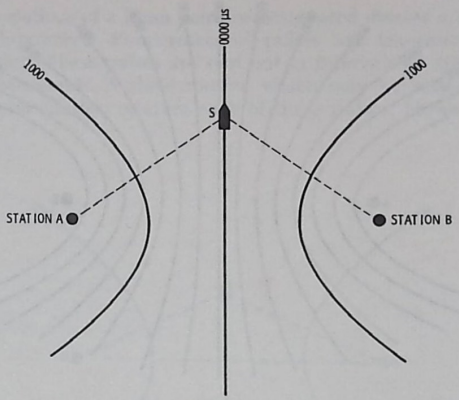
The output of the loop amplifier is applied to the loop-sense adder. Here it combines with the signal delivered from the sense antenna. The adder, too, is in the form of a modulator and produces amplitude modulation of the incoming sense signal. The depth of the modulation is proportional to the angular difference between the goniometer rotor and the null position it is seeking. The 75-hertz modulation changes in polarity from one side of the null to the other, causing the phase of the modulation envelope to be determined by the displacement direction away from the null position. Thus, the output produced contains information relative to angular position and phase. The output of the adder goes to zero on a null position because of the absence of loop signal.

A bandpass filter and then an up-conversion mixer follow. Note that the output of the frequency synthesizer is applied to this mixer as well, resulting in an 8-MHz output which is supplied to a succeeding i-f amplifier. The i-f signal contains the error-signal modulation as well as the modulation from the received station. After amplification and detection, the ac component of the error-signal modulation is used as an error signal which is applied to the loop servo amplifier. It is this component, after being shifted in phase by 90°, that is supplied to the changing-phase winding of the servo motor. This causes the motor to rotate the goniometer rotor until the true null position is found.

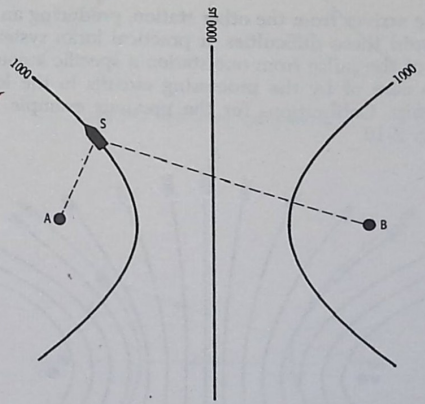
The frequency synthesizer generates the highly stable local-oscillator components that permit one to tune the automatic direction finder over the 190-550 kHz frequency range. In the receiver-only mode, the unit can be operated on these frequencies or on the 2182-kHz distress band by switching the 2182-kHz VCXO circuit into operation. The local oscillator which is center-tuned to 10.182 MHz (to obtain the 8.0-MHz difference frequency) can be varied approximately ±15 kHz, and the receiver is tunable between 2167 and 2198 kilohertz.

LORAN

As mentioned at the beginning of this chapter, a loran system evaluates the time difference between signals arriving from the coastal loran stations instead of the direction of signal arrival as interpreted by a radio compass. Radio waves travel at a constant velocity. If a unit is aboard the ship shown in Fig. 2-8, one can determine the difference in signal arrival time from stations A and B. For example, if the signals at A and B are sent out simultaneously and arrive at exactly the same time at the ship, it is an indication that the ship is traveling along a line that is exactly halfway between stations A and B. If the A signal arrives before the B signal, the ship is at some point between the center line and station A. Conversely, if the A signal arrives after the B signal, it means the ship is somewhere between the center line and station B. In fact, a series of hyperbolic lines showing the time positions can be



(A) Ship equidistant from stations.



(B) Ship nearer station A than B.

Fig. 2-8. Basic principle of loran.

drawn on a map. Line calibrations indicate differences in arrival times (Fig. 2-9).

There are some problems with this basic plan. The main problem is the difficulty of determining which of the two pulses arrives first. There is also a possibility, at certain locations, that one pulse will not conclude

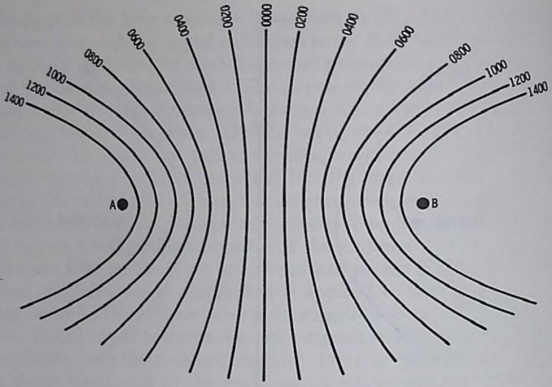


Fig. 2-9. Loran lines of equal delay.

before a pulse arrives from the other station, producing an overlap condition. To avoid these difficulties, a practical loran system delays the transmission of the pulse from one station a specific amount. This fact can be taken care of by the processing circuits in the loran receiver aboard the ship. Calibrations for the previous example would be as shown in Fig. 2-10.

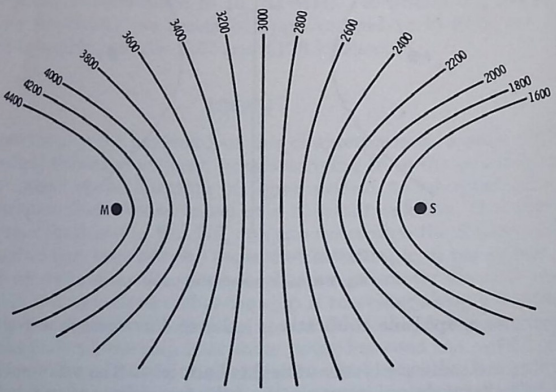
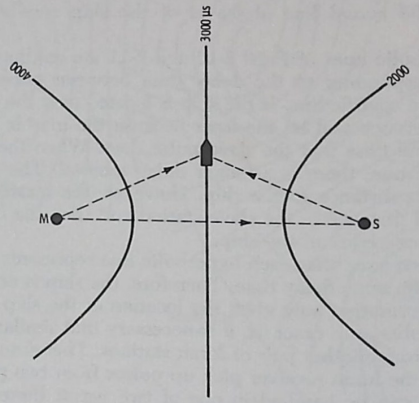
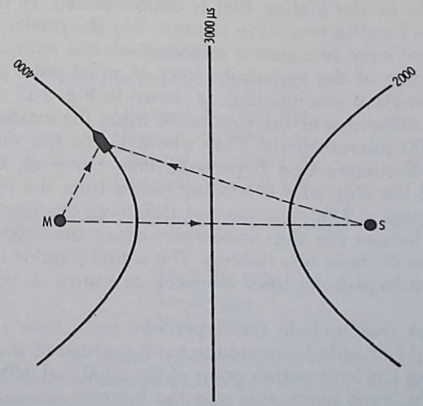


Fig. 2-10. Hyperbolic equal-delay lines of a loran system.

The two stations of a loran pair are designated *master* and *slave* stations. High-powered 40-microsecond pulses are transmitted by the master station. These pulses are sent out at intervals of approximately 40,000 microseconds. A slave station, which may be several hundred miles from the master, receives each of these pulses. However, it does



(A) Ship equidistant from stations.



(B) Ship nearer master than slave.

Fig. 2-11. Practical master-slave lor...

not transmit its own pulse until after a specific delay time, approximately equal to one-half of the pulse repetition period.

A ship picks up both groups of pulses. Through the use of an accurate processing system including a time sweep and oscilloscope display, it is possible to ascertain the difference in arrival time between the pulses from the master and slave stations. This can be converted to distance, and the actual line of travel of the ship can be ascertained (Fig. 2-11).

The hyperbolic lines of Figs. 2-10 and 2-11 are calibrated in microseconds corresponding to the delay time between pulses for a ship sailing along a specific line. If the ship is located near the slave station, the time difference will be the least because the master pulse arrives about the same time that the slave pulse does. When the ship is near the master station, there is a longer delay interval. The master pulse travels a short distance to the ship. However, the master pulse must travel the full distance to the slave station and then the delayed slave pulse must come back to the ship.

It must be stressed that each hyperbolic line represents a line corresponding to the same delay time. Therefore, the ship is not located exactly. The information only gives the location of the ship along a specific line. To obtain an exact fix, it is necessary that similar information be obtained from another pair of loran stations. Therefore, an exact fix requires that the loran receiver pick up pulses from two pairs of loran stations. This can be handled in one of two ways: there can be two separate master stations and two separate slave stations, or it is possible to use a single master station that is double-pulsed. In this case, one master station handles two slave stations, and the results are the same as though there were two master stations.

The combining of the hyperbolic lines of equal pulse delay for two pairs of master-slave combinations is shown in Fig. 2-12. In the example, the time difference at the ship when using the master station and slave 1 is 3400 microseconds. This would locate the ship anywhere along the 3400-microsecond hyperbolic line. However, the loran receiver aboard the ship also is reading pulses from the master station and slave 2, and a 2400-microsecond difference reading is obtained. This reading locates the ship somewhere along the 2400-microsecond hyperbolic line of these two stations. The actual position of the ship is where the two hyperbolic lines intersect, as shown in the lower half of Fig. 2-12.

Sailing maps that include the hyperbolic loran lines are available. Thus you would be able to locate the exact position of the ship on the map by finding the intersection point of the 2400 and 3400 loran time-difference lines. Such maps also give the location information for the various master and slave stations as well as other important designations and frequency information.

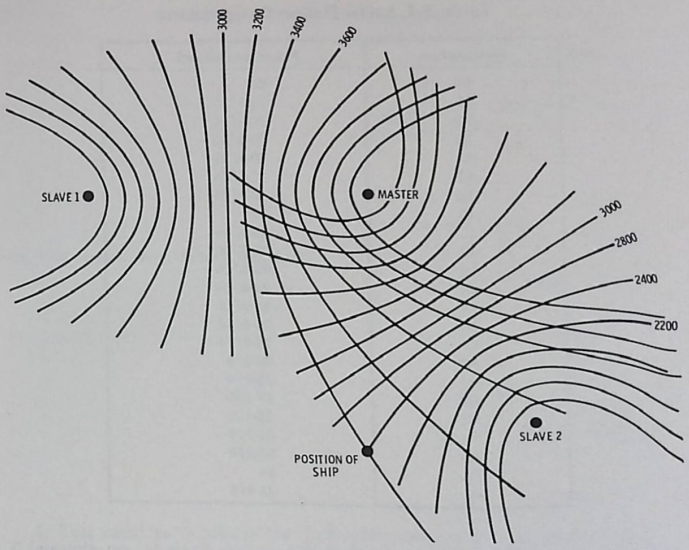


Fig. 2-12. Example of a loran fix.

Station Frequencies and Designations

There are four loran frequencies, as follow:

Channel 1—1950 kHz
Channel 2—1850 kHz
Channel 3—1900 kHz
Channel 4—1750 kHz

Transmissions are also designated according to their basic pulse-repetition rates:

H—33⅓ pps
L—25 pps
S—20 pps

However, each of the above three groups is further broken down into more specific designations as shown in Table 2-1. On loran maps and charts, the master and slave stations are designated in such a manner that the three previous data are available for adjusting the loran receiver to tune in specific pairs of loran coastal stations. For example, a

Table 2-1. Loran Station Designations

Designation	Pulses per Second
S0	20
S1	20-1/25
S2	20-2/25
S3	20-3/25
S4	20-4/25
S5	20-5/25
S6	20-6/25
L0	25
L1	25-1/16
L2	25-2/16
L3	25-3/16
L4	25-4/16
L5	25-5/16
L6	25-6/16
L7	25-7/16
H0	33-3/9
H1	33-4/9
H2	33-5/9
H3	33-6/9
H4	33-7/9
H5	33-8/9
H6	34
H7	34-1/9

designation of 3H7 would mean that the station operates on channel 3 using the highest-frequency pulse repetition rate, which will have a precise recurrence rate of 34⅑ pps. A designation 1L5 refers to a station transmitting on channel 1 and have a pulse repetition rate of exactly 25$\frac{5}{16}$ pps.

A bit of additional information is given on each hyperbolic line of the loran map. Such a designation could be 3S2-2400. This refers to channel 3 using the slowest pulse repetition rate with an exact value of 20$\frac{2}{25}$ pps. Furthermore, the 2400 refers to the 2400-microsecond time-difference line for this particular master-slave combination.

The Loran Receiver

An example of how you would obtain a fix is as follows:

1. After the loran receiver has been placed in operation according to the normal operating procedure, set the station selector switches correctly.
2. Set the channel switch for the proper one of the four loran channels. If you want to tune in station 2L6, set the switch to channel 2.
3. The basic prr switch should now be set to L. Finally, the specific prr switch should be set to position 6 to obtain an exact repetition rate of 25$\frac{5}{16}$ pps.

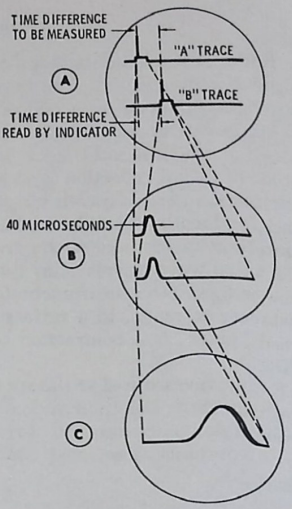


Fig. 2-13. Typical loran display waveforms.

4. You must now adjust the indicator section of the loran receiver. Master and slave pulses will be seen (A of Fig. 2-13). The master signal shown on the top line is now moved atop the A pedestal. The B pedestal is moved under the slave signal of the bottom line.

   Now it is possible to adjust the receiver so that only the pedestal signals are displayed (B of Fig. 2-13). The delay control is now adjusted until the leading edges of the master and slave signals coincide as in C of Fig. 2-13.
5. The indicator readout now displays the delay time. Knowing this reading, you can locate the exact line on which the ship is sailing.
6. To obtain an exact fix, it is now necessary to repeat the above procedure using a second pair of loran stations. A second delay readout is obtained, and it can be located in the loran map. The intersection of the two lines fixes the exact position of the ship.

The loran system permits one to obtain an exact map fix. With the same map or an associated chart, an exact position in latitude and longitude can be obtained. The loran receiver requires no directional antenna because the system functions on the basis of signal delay rather than direction of signal arrival. A radio compass is sometimes difficult to tune carefully in a rough sea, because the accuracy of the bearing depends on knowing the exact direction the antenna is pointed to pick up each coastal station.

RADAR PRINCIPLES

Radar is fundamentally a distance-measuring system using the principle of radio-echoing. You have heard an echo of your own voice as it has been bounced off a cliff or a distant large-area reflecting surface. Equipped with an accurate timing device plus a knowledge of the speed at which sound travels, you can determine just how far away the point of sound reflection is located. You have heard that bats in their nocturnal and cave travels use supersonic sounds for obstacle avoidance and for locating swarms of insects. The porpoise uses similar audio soundings in his underwater travel.

A radio wave travels many times faster than a sound wave. Nevertheless, with suitable instrumentation, radar can be used to measure the distance, or range, to a surface that reflects radio waves. In fact, the word "radar" is a contraction of its definition—RAdio Detection And Ranging.

Radio waves travel at the speed of 300 million meters per second, or approximately 186 thousand miles per second. These figures can be brought down accurately to any number of practical rule-of-thumb distance constants. The most common of these constants are given in Chart 2-1.

Chart 2-1. Radar Wave Propagation

186,000	Miles per Second
162,000	Nautical Miles per Second
3×10^8	Meters per Second
3.28×10^8	Yards per Second
0.186	Statute Miles per Microsecond
0.162	Nautical Miles per Microsecond
328	Yards per Microsecond
	Radar Timing
10.75	Microseconds per Mile
12.36	Microseconds per Nautical Mile
164	Yards per Microsecond
0.081	Nautical Miles per Microsecond

It must be stressed that radar ranging is a two-way process. As shown in Fig. 2-14, the radio wave must travel out and back, and therefore the distance that the wave travels is twice the distance between the radar and the reflecting obstacle. In terms of nautical measurement, a radio wave travels 162,000 nautical miles per second. This corresponds to 0.162 nautical mile per microsecond (one microsecond equals one millionth of a second).

Because the radio wave must travel out and back, the actual radar-range velocity is usually stated as 0.081 nautical mile per microsecond.

In other words, an obstacle 0.081 nautical mile away from the radar would require a total radar wave travel time of one microsecond (one-half microsecond out and one-half microsecond back).

Since a nautical mile is equal to 2027 yards, the velocity of radio-wave travel is equivalent to 328 yards per microsecond. However, effective radar velocity for range measurement purposes is again one-half of this true radio-wave velocity; it is 164 yards per microsecond.

In the example of Fig. 2-14, the distance to the shore line is to be determined. The radar instrumentation indicates that the radar wave in traveling out and back requires an elapsed time of 123.44 microseconds. This indicates that the range to the nearest land is 10 nautical miles (0.081 × 123.44).

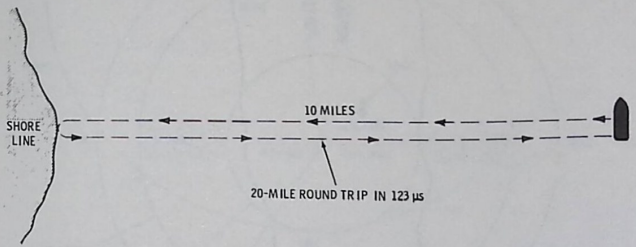


Fig. 2-14. Using radar to determine the distance to land.

In using a radar set, it is not necessary to clock how many microseconds it takes the radio wave to travel out and back, or to make any sort of calculation using radar range velocity and elapsed time. The radar set as such is calibrated in terms of range. The radar display directly indicates the distance to a reflecting surface.

The radar display may indicate the typical ranges shown in Fig. 2-15. If it is indicating that your position is 1000 yards to the left bank and 800 yards to the right bank, the actual radar signals are making round-trip excursions in 6.1 (1000/164) and 4.88 (800/164) microseconds, respectively. Up ahead there is another vessel some 500 yards on the left, and 2000 yards ahead is a pair of buoys. These correspond to elapsed times of 3.05 and 12.2 microseconds, respectively.

The display of information shown in Fig. 2-15 is quite similar to what you would see on the most common type of radar display. However, the background would be black, and the actual targets would be illuminated. In addition, there would be several concentric illuminated rings which are called *range rings* or *range marks*. They calibrate the display in terms of distance from the radar set. In the example, calibrations are in terms of thousands of yards.

A radar set is not only able to determine the range to a point of reflection, but it also determines the bearing of the point of reflection with relation to the position of the radar, or with respect to some reference direction such as true north. For the usual shipboard radar, the ship heading is often established as the zero degree reference angle, as depicted in Fig. 2-15.

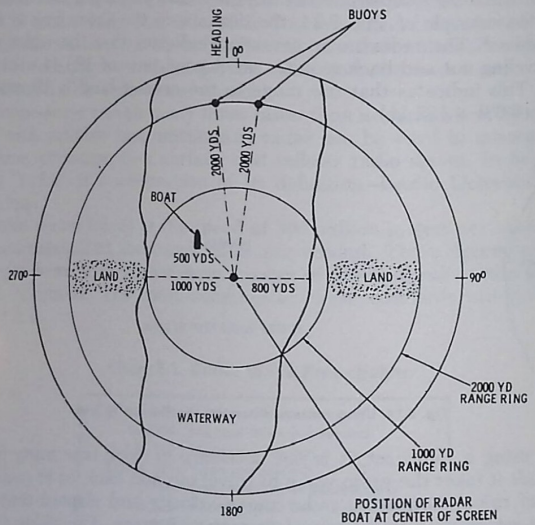


Fig. 2-15. Typical inland water conditions as evaluated by radar.

Radar signals are transmitted on an extremely high frequency. Therefore the wavelength is very short, and it is possible to build highly directional antennas with practical dimensions. Microwave signals travel in straight light-beam fashion. These characteristics make it possible to concentrate the radar energy into a small-diameter, pencil-like beam. Thus, the direction from which a reflection returns to the radar set is indicated by the angular position of the radar antenna at that instant. This fact is illustrated in Fig. 2-16. If the antenna is pointing directly north, there will be a reflection from obstacle 1. Since the reflection occurs when the antenna is pointing in the direction of the ship's heading, it is indicated that the obstacle is at zero degrees, or dead ahead. Likewise, with the antenna directed at an angle 30° or 135° relative to the ship's heading, there will be a return echo indicating that there are

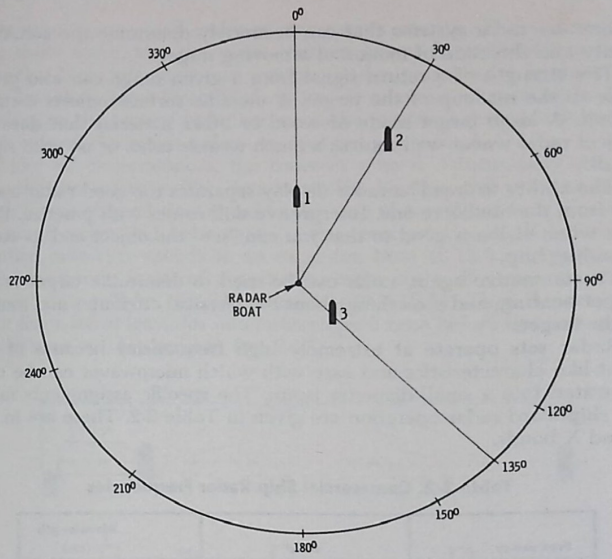


Fig. 2-16. Taking bearings with a radar display.

obstacles in these directions. At other angles in the example of Fig. 2-16, there will be no return echo signals.

In summary, a radar is able to determine the range to an obstacle or target by evaluating the time needed for a signal to go out to the target and return. The bearing of the target is shown by the angle of the antenna when the target signal returns. These two factors are of particular importance in using radar for marine navigation and safety.

Radar can be used to evaluate additional attributes of a target that is returning echoes to the set. The size of the image as it appears on the radar display tube gives some inkling of the dimensions of the target. A large vessel produces a larger mark or "blip" than a smaller vessel produces; a buoy appears smaller than a vessel. The shore line illuminates a much larger segment of the display, indicating a large land mass. A large island illuminates a larger area on the radar display tube than does a smaller island.

The greater the range to a target of a given size, the smaller is its corresponding blip on the display screen. A stationary target appears stationary on the display. The faster the target moves, the faster it moves across the display tube as compared to a slower moving target.

There are radar systems that can accurately determine the actual velocity and direction of motion of a moving target.

The strength of a return signal from a given range can also give a clue to the makeup of the target. A metallic surface reflects a strong signal. A large target made of wood or other material that does not reflect radio waves well returns a much weaker echo, or no echo signal at all.

The ability to "read" a radar display separates the good radar operator from the mediocre one. Interpretive skill comes with practice. Practice when vision is good so that you can "see" the object and its corresponding blip.

To summarize again, radar can be used to determine target range, target bearing, and something about the physical attributes and motion of the target.

Radar sets operate at extremely high frequencies because of the light-like characteristics and ease with which microwaves can be concentrated into a small-diameter beam. The specific assignments made for shipboard radar operation are given in Table 2-2. These are in the S and X bands.

Table 2-2. Commercial Ship Radar Frequencies

Frequency	Band	Wavelength (cm)
2900-3100	S	10.3 -9.7
5470-5650	X	5.5 -5.3
9300-9500	X	3.22-3.15

It is convenient to refer to the wavelength of the various radar frequencies in terms of centimeters instead of meters. A convenient conversion formula between frequency and centimeter wavelength is:

$$\text{centimeter wavelength} = \frac{30{,}000}{\text{frequency megahertz}}$$

It is also convenient to relate centimeters and inches because of the practical dimensioning of waveguides, antennas, and other microwave components.

$$1 \text{ centimeter} = 0.394 \text{ inch}$$

$$1 \text{ inch} = 2.54 \text{ centimeters}$$

PULSE CHARACTERISTICS

There are various forms of radar transmission. The most common type of transmission is called *pulse radar*. Pulse radar sets are widely installed on small boats and ocean-going vessels. A high-powered radar

transmitter sends out a pulse of microwave energy. The transmitter then shuts down, and the radar receiver listens for returning echoes from this burst of microwave energy. Radar pulses vary in duration from less than one microsecond up to five or more microseconds. Depending on the type of radar service to be rendered, from sixty pulses up to several thousands pulses are sent out per second.

Under all circumstances, the transmit time is substantially shorter than the receive time. This is a necessity, because the receiver must listen for an elapsed time equal to the time of travel out to a target at maximum range and back again to the receiver. Recall that a radar nautical mile corresponds to an excursion time of 12.3 microseconds. If the maximum range of a particular radar set is 40 miles, the total elapsed time will be 492 microseconds (40 × 12.3). Thus the receiver must listen for at least this minimum elapsed time before the next pulse can be sent out, as shown in Fig. 2-17.

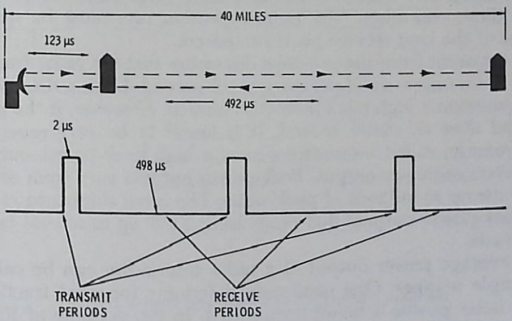


Fig. 2-17. Transmitting and receiving periods of a radar system.

In the illustration, it has been assumed that the duration of the pulse is 2 microseconds. The time spacing between the end of one pulse and the beginning of the next pulse has been assigned a value of 498 microseconds. Thus, the radar pulse will have adequate time to travel 40 miles and return. Of course, the receive time is more than adequate for any target that is nearer to the radar set.

If the conditions just mentioned apply to a maximum 40-mile range, what is the maximum number of 2-microsecond pulses that can be transmitted per second? The time interval between the start of one pulse and the start of the next corresponds to 500 microseconds. This is the pulse period. The transmission frequency can be determined by dividing the pulse period into one million microseconds (1 second).

$$\text{frequency or prr} = \frac{1 \text{ second}}{\text{period}} = \frac{10^6 \text{ microseconds}}{500} = 2000$$

The number of pulses that can be transmitted per second is 2000, and the pulse-repetition rate (prr) in pulses per second (pps) is said to be 2000.

Of course, a greater range of transmission requires a longer listening period. Consequently, fewer pulses may be transmitted per second. For a shorter range, the pulse-repetition rate can be even higher, because the listening period can be correspondingly less.

Fig. 2-17 shows the timing of a radar signal which has traveled out to a target 40 miles away and returned over the same path to the radar set. A second target is also shown on the illustration. It returns a signal from a distance of approximately 10 miles. Notice that its echo comes back much earlier than the previous echo signals. Its excursion trip time is only 123 microseconds.

Some radar sets have ranges in excess of several hundred miles. Under these conditions, the pulse-repetition rate must be quite low because of the long receive period required.

It is apparent from the previous discussion that the radar transmitter functions for only a small portion of each second. During these intervals of transmission a high peak power is radiated. However, if the power is averaged over an entire second, it is found to be very much lower. Consequently, radar transmitters have a high peak-power output but a low average-power output. Peak-power outputs vary from one thousand watts up to millions of peak watts. The usual shipboard radar sets have peak-power outputs that range from 3 kW up to several hundreds of kilowatts.

The average power output of a radar transmitter can be calculated in a simple manner. One need only determine for what fraction of a second radar power is being transmitted. In the example of Fig. 2-17, the pulse duration was 2 microseconds, and 2000 of these pulses were transmitted each second. Consequently, the transmit time per second is:

$$\text{Transmit Time} = 2\ \mu s \times 2000 = 4000\ \mu s$$

The radar transmitter transmits 4000 microseconds out of each one million microseconds. This quotient is referred to as the *duty cycle* of the radar.

$$\text{Duty Cycle} = \frac{\text{Transmit Time}}{10^6} = 0.004$$

Furthermore, if the peak power of the radar is known, the average power can be determined by multiplying the peak value by the duty cycle. Again in the previous example, the average power is calculated to be:

$$\text{Average Power} = 0.004 \times \text{Peak Power}$$

The higher the duty cycle, the greater the average power output is. Duty cycle is increased by increasing pulse duration and/or pulse-repetition rate.

FUNCTIONAL BLOCK DIAGRAMS

The functional block diagram of a typical radar installation is given in Fig. 2-18. Study the diagram carefully and understand the basic objective of each major unit. Know this block diagram and those that follow in this chapter so well that you can draw them from memory. This understanding of the fundamental operator of a radar set is important in preparing for your radar license examination.

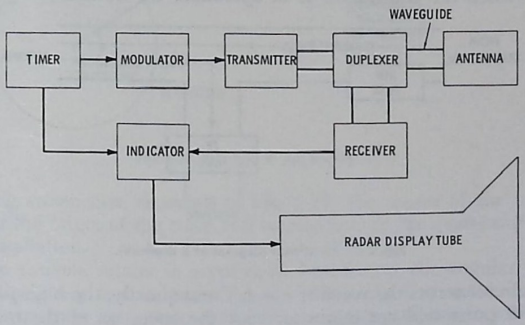


Fig. 2-18. General functional block diagram of a radar set.

The major units are shown in the block diagram. The timing center of a radar set is called the *timer*. It generates a basic set of timing pulses that trigger and control the generation of the pulses that turn on the radar *transmitter*. In effect, the timer decides the pulse-repetition rate of the radar system.

The transmitter contains the high-powered microwave generator. It is usually a magnetron power oscillator. The function of the magnetron is to generate a high-powered rf pulse of proper duration and repetition rate. The power pulses that turn on the magnetron are generated in the *modulator*. The modulator pulse generator is always under the control of timing pulses from the timer.

The oscillator operates only during the power pulse and sends out a burst of microwave energy through the *duplexer* and *waveguide* to the antenna. Then the transmitter shuts down, and the *receiver* listens.

The return echoes from a distant target strike the same antenna, and through the waveguide and duplexer, the return signals enter the receiver. Here they are increased in level and demodulated. The signals are next applied to an *indicator* and are observed on a special cathode-ray oscilloscope *display tube*. The scope display and associated circuits are calibrated by the timer so that an actual time measurement can be made between the time of pulse transmission and the time of echo arrival. In so doing, a conversion is made between time and distance.

The indicator display also takes into consideration the direction to which the antenna is pointed when an echo returns. Consequently, the radar display can also be calibrated in terms of bearing.

Two special devices, included in the duplexer (Fig. 2-19), are tr and anti-tr (or atr) tubes. The tr, or transmit-receive, tube protects the receiver when the transmitter is in operation. On transmit, it places a

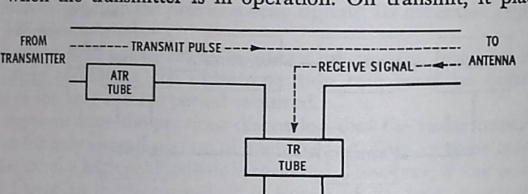


Fig. 2-19. Functional diagram of a duplexer.

short circuit across the receiver input. Consequently, the high-powered transmit pulse will not injure or delay the operation of the radar receiver. The atr device permits the receiver to make full use of a weak returning echo signal. It blocks the return signal from the transmitter section and directs the return signals into the receiver.

The receiver is very sensitive, and to maintain the best signal-to-noise ratio it converts the high-frequency microwave signal to a lower i-f frequency before amplification. The signal is then amplified and demodulated in preparation for its application to the indicator section.

In the indicator section of the radar set, there is further signal processing along with the introduction of calibration signals which are formed under control of the timer. Also under the control of the timer, the indicator develops the necessary sweep waveforms used to deflect the beam of the crt radar display tube.

RADAR DISPLAYS

Range and bearing are displayed on the plan-position indicator (ppi) screen. The basic ppi presentation is a circular one that is traced out by

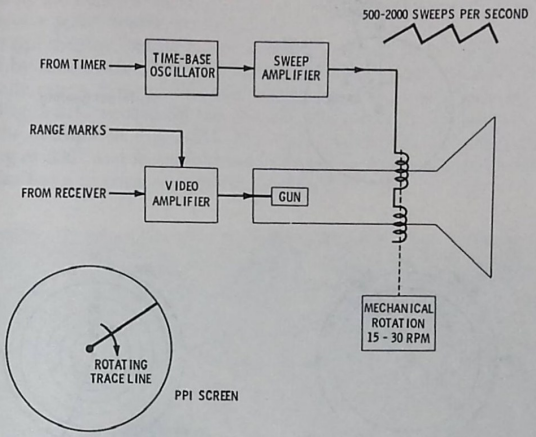


Fig. 2-20. Principle of ppi display.

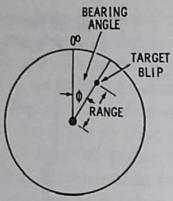
a rotating sweep line, as shown in Fig. 2-20. The center of the round screen is the origin of the trace and corresponds to the position of the radar installation.

As the antenna rotates in a ppi radar installation, the angular position of the sweep line indicates the azimuth angle of the antenna. In fact, the ppi trace line rotates (15 to 30 rpm) in synchronism with the antenna, always indicating the azimuth angle or bearing of the antenna relative to a zero reference angle. The reference angle can be the ship's heading. In other installations, the refernce angle can be true north.

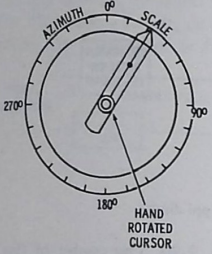
As it rotates, the trace line causes some illumination of the screen. An arriving target signal causes a brighter illumination of the screen. The return target signals are applied to the electron gun of the radar cathode-ray tube and cause intensity modulation of the beam. This process can be compared to the influence of a video signal applied to the grid of a television picture tube.

If a target is "painted" on the screen by the rotating trace line, as in Fig. 2-21A, its angular position on the display tube shows the target bearing. Often a transparent cursor is included. It can be hand rotated until its hairline, as shown in Fig. 2-21B, crosses the target and sets off the bearing on the azimuth scale that surrounds the periphery of the display tube (Fig. 2-22).

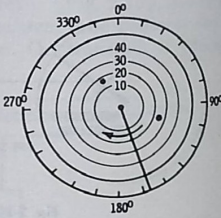
The range of the target is disclosed by the distance between the target and the center of the display. A target at maximum range would



(A) Target bearing.

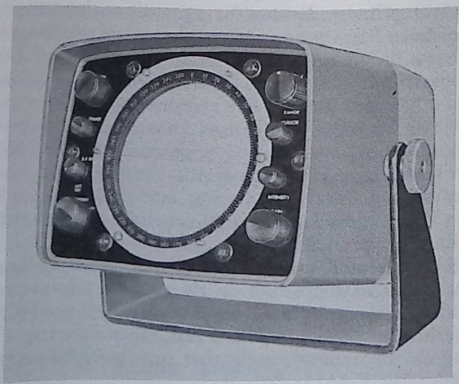


(B) Transparent cursor.



(C) Concentric range rings.

Fig. 2-21. Plan-position indicator display.



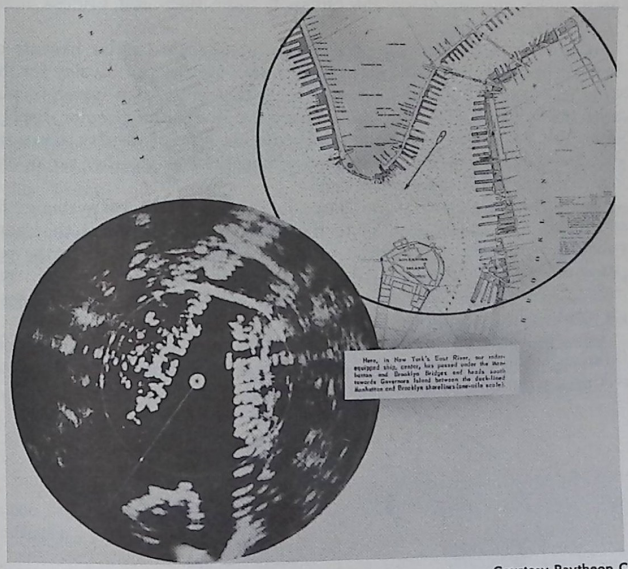
Courtesy RCA

Fig. 2-22. Small-boat radar showing ppi screen and azimuth scale.

appear at the edge of the display. A nearer target would appear on the screen at a point nearer to the origin.

The ppi display can be range calibrated. The range calibrations are set off by concentric circles referred to as range rings. Again, assuming a 40-mile range, it is possible that there would be four concentric rings, as in Fig. 2-21C, setting off the 10-, 20-, 30-, and 40-mile ranges.

In the example of Fig. 2-21C, there are two targets. One appears at a bearing of 330° and is approximately 18 miles away. A second target at 25 miles has a bearing of approximately 110°.



Courtesy Raytheon Co.

Fig. 2-23. Radar display of New York harbor.

The ppi radar system does not only pick out a few isolated targets; rather, it picks up any target capable of returning a signal, so long as that target is within the useful range of the radar set. The targets are painted on the screen regardless of their bearing. In fact, a ppi presentation is almost map-like.

A radar picture of New York harbor is shown in Fig. 2-23. Make a comparison between what is seen on the radar screen and the map of

the same area shown beside the radar display. Your location, at the center of the radar screen, corresponds to a position on the East River. In fact, you have just passed under the Manhattan and Brooklyn bridges and are moving between the edge of Manhattan and Governor's Island. Notice how the radar sets off the land masses with a large area of illumination. The water area is dark. The docks can be distinguished along the shore lines.

Another typical ppi presentation is shown in Fig. 2-24. This type of pattern can be seen in moving along a bay or inland waterway. The actual buoys along the channel can be seen. The radar shows other small boats moving along the channel; shore lines and bridges stand out clearly.

In summary, the ppi screen is ideal for shipboard radar because of its map-like type of display. Aircraft radars use the ppi display for the same reason. Likewise, land-based radar that must keep watch on aircraft traffic in all directions can make good use of the circular display. Although the ppi is by far the most common type of display, there are specific uses for other types in such applications as weather radar, aircraft landing, and missile tracking.

Two other basic scans are shown in Fig. 2-25. In both systems, the return echo signal is applied to the grid-cathode circuit of the radar tube, and intensity modulation of the beam similar to that in the ppi presentation is caused. However, a scanning raster is traced on the radar screen. This raster is similar to the lined raster that can be seen on a television picture-tube screen.

Usually the presentation is adjusted so that the lines show only faintly. When an echo signal arrives, it causes a brighter illumination of one particular point on the raster.

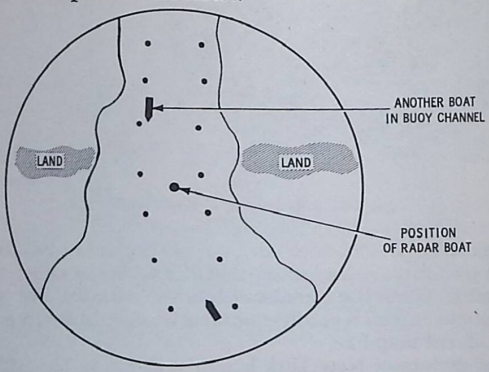


Fig. 2-24. Buoy-channel display.

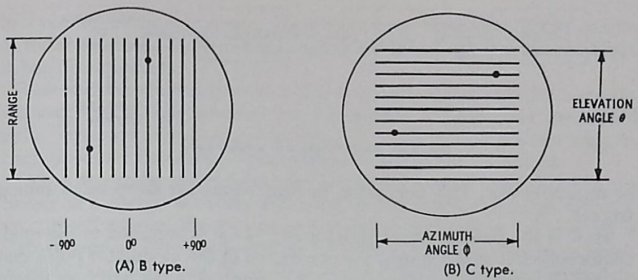


Fig. 2-25. B-type and C-type radar displays.

In B-scan, the vertical motion of the scanning beam corresponds to the target range. Thus the scanning beam as it moves from bottom to top of the display has a timing that corresponds to the round-trip excursion for a radar pulse in traveling out to and back from a maximum-range target.

The vertical coordinate of the presentation is calibrated in range. The horizontal coordinate is the azimuth and corresponds to the bearing of the antenna. For this type of scan, the antenna usually covers a 90° sweep on each side of dead ahead. The blip as it appears on the radar screen indicates both the range and bearing of the target.

The C-type display is similar but displays the elevation angle of the target and the azimuth angle instead of the range and azimuth angle. This type of radar is generally used for tracking, because it displays the horizontal (azimuth) and vertical (elevation) angles of the target.

BASIC UNITS

For convenience, a radar set may be considered to consist of four basic units. These are the timer, transmitter-modulator, receiver, and indicator.

Timer

The timer, or synchronizer (Fig. 2-26), is the timing center of the radar system. Often a stable sine-wave oscillator is operated at the pulse-repetition frequency of the radar system. The output sine wave is applied to a limiter-clipper circuit which forms a squared wave. A follow-up differentiating circuit shapes the square wave into a pulse.

The actual trigger or timing pulse is formed in one of two ways. The differentiated pulse itself can be further shaped to form a steep-sided and short-duration pulse that can act as a trigger. In an alternate arrangement, the pulse can be used to synchronize a blocking oscillator

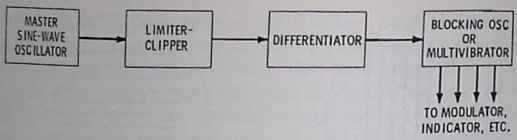


Fig. 2-26. Block diagram of a radar timer.

or multivibrator. This generator, in turn, forms the steep-sided timing trigger.

How is the timing trigger pulse used? (1) It is supplied to the modulator where it synchronizes the generation of the modulator pulse that eventually fires the magnetron. (2) It is supplied to the indicator where it initiates the trace portion of the crt sweep. Hence, the start of the trace on the screen coincides with the transmit pulse. (3) It triggers the range-mark generator which forms the special calibration signals that place the range rings on the ppi display. (4) It triggers various other special circuits according to the design features and intended application of the particular radar set.

Transmitter-Modulator

The transmitter-modulator generates the microwave pulse sent out by the antenna. The basic functions of the transmitter and associated duplexer were stated in the discussions associated with Figs. 2-18 and 2-19. The block plan of the modulator section is shown in Fig. 2-27.

The modulator generates the high-powered switching pulse needed to turn on the magnetron oscillator an exact number of times each second. In generating the high-powered microwave burst, the magnetron anode-cathode voltage (when in oscillation) must be thousands of volts, and the magnetron tube must draw a high peak current. In fact, because of magnetron and other circuit losses, the power in the pulse

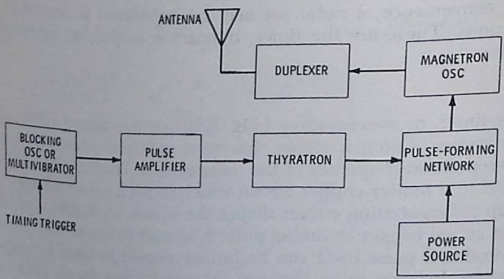


Fig. 2-27. Transmitter-modulator block diagram.

that turns the magnetron on and off must be greater than the rf output of the magnetron. Thus a radar modulator uses high-power and high-voltage components.

The basic modulator-control pulse is usually generated by a multivibrator that is synchronized by the timing trigger. The generated pulse, after amplification and shaping, is used as a thyratron trigger. High-powered switching is the responsibility of the thyratron.

When the radar is listening, the modulator power supply stores up energy in a special network. When the transmit pulse is to go out, the thyratron fires, and the energy stored in the network is released as a high-voltage and high-powered pulse to the magnetron. The magnetron oscillates and sends out the transmit pulse. The network and thyratron switch are designed to turn on the magnetron quickly, hold it on for a specific pulse duration, and then shut it down quickly.

Receiver

The receiver (Fig. 2-28) amplifies and demodulates the returning target signal. Usually the same antenna is used for transmitting and receiving. Sometimes a separate receiving antenna is positioned near the transmitting antenna.

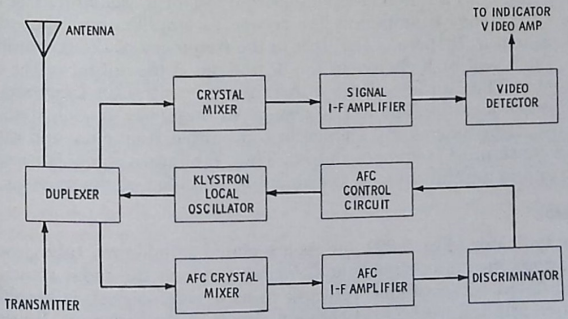


Fig. 2-28. Block diagram of a radar receiver.

The receiver can be a single unit. Often it is in two parts, the rf head mounted at the antenna and the other part of the receiver at the indicator.

The rf head usually includes a crystal mixer, a klystron local oscillator, and two or more stages of i-f amplification. Additional i-f amplifier stages are included in the second part of the receiver. In recent years, tunnel diodes, transistors, and other solid-state devices have

become more common in microwave equipment. Microwave tubes and other special circuits are covered later in this chapter.

Two crystal mixers are generally used. One supplies target i-f signals to the high-gain i-f amplifier. The bandwidth must be such that the return target signals will not be distorted and will therefore appear as bright and distinct blips on the radar screen. After i-f amplification, the target signal is demodulated by an a-m video detector. The demodulated signal is increased in magnitude and applied to the indicator circuit.

The second crystal mixer is used for automatic frequency control (afc). The afc makes certain that the receiver displays a maximum sensitivity to returning target signals by keeping the klystron on the proper frequency so that the target signal is always converted to the desired i-f frequency.

The magnetron frequency may drift, and therefore the difference frequency between the returning target signal and the local-oscillator frequency may not match the i-f frequency of the receiver. It is the purpose of the afc system to make the oscillator frequency track any change in magnetron frequency. Therefore the difference frequency will always be the exact i-f frequency.

In the afc crystal mixer, a small component of the transmitted pulse is compared with a signal component from the local oscillator. The difference frequency is amplified in a second i-f amplifier and applied to a discriminator. If there is any drift in the frequency of the transmitted pulse, there will be a change in the dc voltage at the output of the discriminator. This "error" voltage is then used to control the frequency of the klystron local oscillator. The change in frequency is such that the local oscillator follows any change in transmitted frequency and maintains a constant i-f frequency output. Thus, the return signal is ensured of maximum amplification in the signal i-f amplifier of the receiver.

Indicator

The indicator (Fig. 2-29) and its associated cathode-ray tube process the various incoming signals and display them on the radar screen. A demodulated target signal, referred to as a video signal, is amplified and then applied to the grid-cathode circuit of the radar crt. By varying the crt beam strength, the signal causes an illuminated bright mark to appear on the fluorescent screen of the radar tube.

Range-mark pulses are also generated in the indicator. They are, of course, formed under synchronization of the trigger pulses from the timer. These pulses are mixed in the video amplifier with the incoming return signal; both signals are then applied so as to intensity-modulate the beam of the radar display tube.

In the radar display, it is necessary to turn off the scan beam during retrace from the outer periphery of the screen back to the center, prior

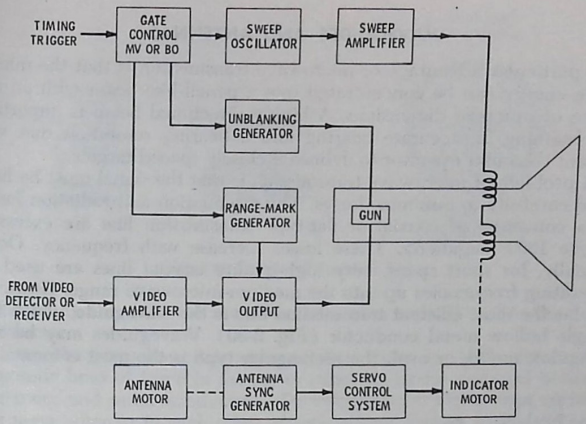


Fig. 2-29. Block diagram of indicator and servo system.

to the start of a new trace. In the indicator circuit, *gating* or *blanking* pulses are used to turn off the scanning beam during the retrace time.

Still another function of the indicator is to generate the sweep waveform that is applied to the deflection coil of the radar tube. This waveform causes the trace motion of the beam from the center of the radar tube out to the periphery. This trace motion must begin in synchronism with the transmitted pulse. Furthermore, the velocity with which the beam moves from the center to the outer part of the screen must correspond to the travel time of the radar pulse for the particular range setting. Consequently, the generation of the sweep waveform must also be synchronized by the trigger pulse.

One final function of the indicator circuit is to cause the scanning line to revolve about the ppi display in synchronism with the rotation of the antenna. The servo system shown in Fig. 2-29 accomplishes this. The antenna is rotated by a motor. Associated with the rotation of the antenna is a synchro generator. Its signal, through a servo system, controls a servo motor back at the indicator. The indicator motor, in turn, rotates the deflection coil of the radar display tube. When properly phased, the rotation of the deflection coil follows the rotation of the antenna.

Usually when the antenna is pointing dead ahead, the trace line on the display tube is directed upward. As the antenna rotates, the trace line itself rotates around the display screen because the deflection coil is rotated by the synchro motor.

WAVEGUIDES AND ANTENNAS

A particular advantage of microwave transmission is that the microwave energy can be concentrated into a pencil-like beam with an antenna of practical dimensions. A highly directional beam is important in obtaining an accurate bearing and a bearing resolution that will permit the radar operator to delineate closely spaced targets.

A problem of microwave transmission is that the signal must be handled carefully to minimize losses. The attenuation and radiation losses of a conventional coaxial or flat-type transmission line are excessive above 1000 megahertz. These losses increase with frequency. Occasionally, for short spans, very high-quality coaxial lines are used on operating frequencies up into the medium-microwave range. However, by far the most efficient transmission line is the waveguide, which is a single hollow metal conductor (Fig. 2-30). Waveguides may be rectangular, round, or oval; the rectangular type is the most common.

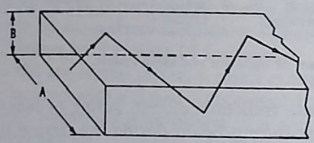


Fig. 2-30. A waveguide.

Waveguides

Microwave energy travels within the metal enclosure of a waveguide by bouncing off the inner walls. There is no significant penetration of the walls and, consequently, no radiation loss. In fact, the waves are reflected off the inner walls with little attenuation loss. Thus the waves propagate along the guide with very little loss, even as compared to the current losses encountered by a lower-frequency wave traveling along a conventional transmission line.

The transmission of microwave energy along a waveguide is in the form of electromagnetic propagation, just as a wave is propagated through space, except that the radiation is confined within the guide. In considering the operation of a waveguide, therefore, we are concerned with magnetic and electric lines of force. These hold the same significance as the rf current and voltage distribution along a regular transmission line.

There are *electric lines of force* between the plates of an operating capacitor, as in Fig. 2-31. There are *magnetic lines of force* about a current-carrying conductor. In the case of an actual coaxial transmission line, there are electrostatic lines of force between the inner and outer conductors, and a magnetic field is set up about the current-carry-

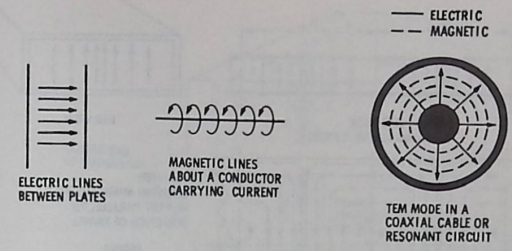


Fig. 2-31. Electric and magnetic fields

ing wire. In this case, the magnetic lines are confined within the outer conductor.

From the preceding, it is apparent that there are both electric and magnetic lines of force in the air or other dielectric material between the inner and outer conductors of a coaxial line. These lines of force are perpendicular to each other and are perpendicular to the direction of current flow in the line, as shown in Fig. 2-31. The electrostatic field configuration for such a coaxial line is said to be *transverse electromagnetic* (tem), because both fields are normal to the direction of wave travel. The transverse electromagnetic mode of operation is common to all types of transmission lines except waveguides.

In the transmission line, the two conductors provide a return path for field energy. A waveguide has only one conductor. There is no physical return path for the rf energy. The changing lines of force must provide the continuous movement and completed loops within the guide. Either the electric or the magnetic field must be oriented in part in the direction of propagation. Since the electric and magnetic fields are always perpendicular to each other, both fields cannot be perpendicular to the direction of propagation. Thus the tem mode is impossible in a waveguide.

There are two basic modes of waveguide propagation. One is called *transverse electric* (te) because the electric field is perpendicular to the direction of propagation (Fig. 2-32). The magnetic field in this case is parallel to the direction of propagation. In the *transverse magnetic* (tm) mode, the magnetic field is perpendicular to the direction of propagation, while the electric field parallels the direction of propagation.

There are various subdivisions of the basic te and tm modes. These are indicated by two subnumerals which indicate the number of amplitude peaks that fall along the long or short walls of the waveguide. The first subnumeral indicates the number of patterns or half periods that fall along the long walls of the rectangular guide (side-to-side *A* dimension of Fig. 2-30). The second subscript indicates the number of pat-

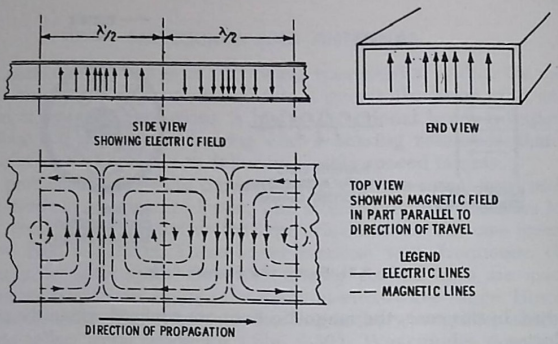


Fig. 2-32. Transverse electric (te_{10}) mode.

terns or half periods that fall along the short walls from top to bottom (*B* dimension in Fig. 2-30).

In the case of the te mode, these patterns are electric field patterns; for the tm mode, they are magnetic field patterns. In the example of Fig. 2-32, the mode is te_{10}, indicating that the electric field pattern shows one pattern from side to side and is uniform from top to bottom.

Waveguide Accessories

Waveguides present various mechanical problems. Bends, turns, and joints can be made, but they must be planned carefully to provide a gradual and smooth transition along the path of propagation. Bends should be beveled or have a large radius of curvature. In this way, discontinuities and harmonics are not introduced into the particular mode configuration. Flange joints are common; they must be smooth and tight-fitting.

There must also be a means of transferring energy from a signal source to the guide. In such a transfer, the waveguide must be excited at the proper mode.

Most microwave tubes, such as magnetrons and klystrons, as well as tr and atr tubes, have waveguide inputs and outputs. Hence, it is possible to use a flange joint. Some microwave tubes employ coaxial input and/or output. In this case, it is necessary to use a probe excitation arrangement, as in Fig. 2-33. An extension of the inner conductor of the coaxial segment extends probe-like into the waveguide. Its electric field is parallel to the probe. Consequently, the electric vector in the waveguide becomes parallel with its short sides and transverse to the long side and the direction of propagation. Oppositely, the magnetic lines of force from the probe, although normal to the electric lines, are parallel

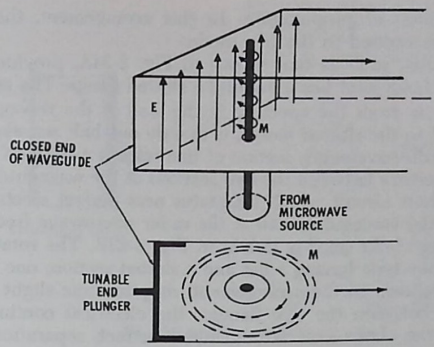


Fig. 2-23. Probe used to excite te_{10} mode in a waveguide.

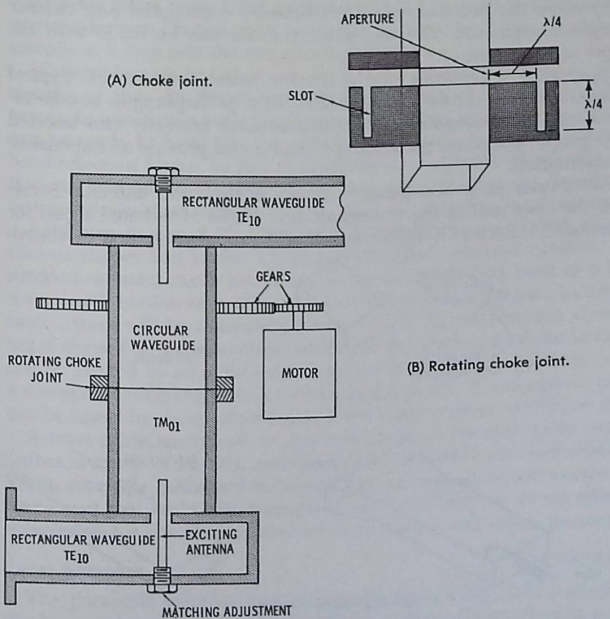


Fig. 2-34. Waveguide accessories.

to the direction of propagation. In this arrangement, therefore, the waveguide is excited in the te_{10} mode.

Choke joints, such as that shown in Fig. 2-34A, provide a smooth, tight fit. A choke joint has a flat and a slotted flange. The entire length of the section, from the aperture in the wall of the waveguide to the shorted end in the slotted flange, is exactly one-half wavelength. Since a shorted half-wavelength section of line reflects a short to its opposite end, the aperture between the two sections at the waveguide wall is an electrical short circuit which maintains near-perfect electrical continuity along the waveguide wall at the radar microwave frequency.

A rotating choke joint is shown in Fig. 2-23B. The rotating joint is again a choke type having a flat and a slotted section; one is fixed and the other rotates. In the arrangement, despite some slight mechanical separation between the two flanges, the electrical continuity is sustained by the choke-joint arrangement. In fact, separations up to as high as several millimeters can be used without a serious disturbance of the energy being propagated along the guide. Two probe arrangements make the necessary transfers between rectangular and circular waveguide segments. The te_{10} mode transfer can be made with the simple arrangement of Fig. 2-34B.

Appropriate accessories can be used to match impedances. Typical arrangements are shown in Fig. 2-35B. Tabs or diaphragms can be inserted into the waveguide. When dimensioned correctly and inserted at the proper positions, these tabs or diaphragms provide an impedance transformation.

Waveguides must also transfer signals to the radar antenna. Sometimes the open end of the waveguide is a source of radiated signal for a parabolic reflector. A better match and proper excitation or *illumi-*

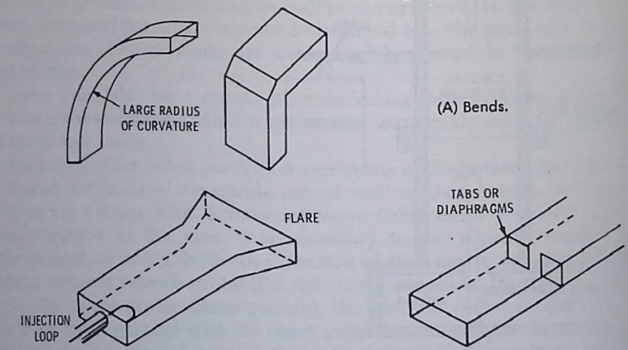


Fig. 2-35. Other waveguide accessories.

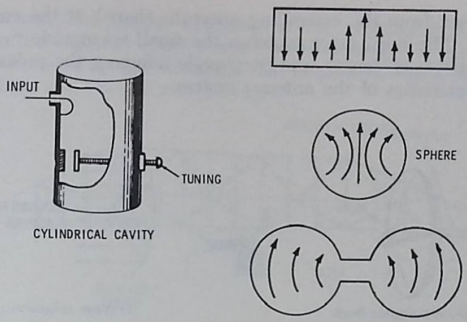


Fig. 2-36. Resonant cavities.

nation of the reflector can be accomplished by tapering the end of the waveguide into a horn. Even a coaxial line can be used to excite such a waveguide horn. In this case, the inner conductor of the coaxial line extends as a loop into the waveguide radiator.

Waveguides can be cut at specific lengths to serve as open- or short-circuits, or they can be made to display capacitive or inductive reactances. In association with diaphragms or external sections, waveguides can be made to have the characteristics of traps, bandpass filters, or band-rejection filters. In fact, a properly dimensioned waveguide section can be made to operate as a series or parallel resonant circuit, just as transmission-line sections can be made to serve similar functions.

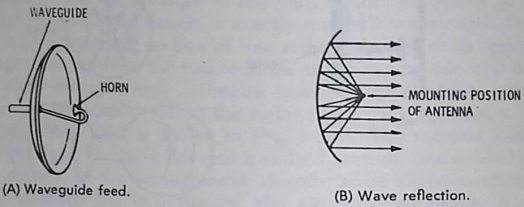
As shown in Fig. 2-36, waveguide segments can be closed off into various shapes and forms. These are all called *resonant cavities.* The simplest resonant cavity can be made by closing off both ends of a half-wavelength section of a rectangular or circular waveguide. In such a cavity, there will be a circulating magnetic field similar to the circulating rf current in a conventional tuned circuit. Such a waveguide cavity can be excited by an inductance loop coming from a coaxial line or by a waveguide coupling system through a slot or iris. A waveguide cavity can be tuned by using either a plunger arrangement or capacitive slugs.

A waveguide cavity can be made to have an exceptionally high Q (often in excess of 10,000), and it is inherently stable and well shielded. When carefully calibrated in association with an accurate micrometer movement and scale, the waveguide cavity can serve as an effective wavemeter for checking microwave frequencies and other parameters.

Radar Antennas

The parabolic reflector and waveguide horn (Fig. 2-37) constitute the basic radar antenna. The microwave pulse is directed onto a para-

bolic reflector from the expanding aperture (horn) at the end of the waveguide. The horn taper matches the small waveguide to the surrounding space; its length and flare angle influence the radiation and gain characteristics of the antenna system.



(A) Waveguide feed. (B) Wave reflection.

Fig. 2-37. Parabolic antenna.

The shape of the parabolic reflector is controlled in a manner that concentrates the rf energy into a single source of radiation that can then be sent out in a single direction. As shown in Fig. 2-37, there are equal angles of wave incidence and reflection at the parabolic surface. Thus, the rays coming off the reflecting surface flow outward in parallel paths. The energy coming off a full parabolic surface of this type is concentrated into a small-diameter pencil-like beam. The larger the parabolic antenna in terms of wavelength, the smaller the diameter of the beam is and the greater the antenna gain.

Sectionalized parabolic reflectors are often employed if a circular beam is not required. Such sectionalized types generate beams of specific vertical and horizontal angles of radiation. At the same time, the physical dimensions of a sectionalized type can be made such that the sections are less awkward in terms of erection space and the need for rotation or scanning.

Parabolic-reflector diameters are at least several wavelengths and often ten or more wavelengths. Power gains of several thousand are practical.

In many radar services, the horizontal radiation angle should be very narrow so as to have a good bearing resolution. However, it is often preferable for the vertical radiation angle to be substantially broader so as to minimize the vertical stability problem. For example, there is considerable vertical motion of a ship because of the waves. Hence, it is very likely that a radar beam would swing above and below the target as the boat "rode the waves." However, this would not be so if the vertical beam from the antenna were rather wide. Hence a common antenna for shipboard radar would be a sectionalized parabola, as shown in Fig. 2-38. In terms of the horizontal beam width, the parabolic section has a large diameter in terms of wavelength; therefore the beam is

quite narrow. The height dimension of the reflector is limited, and therefore the vertical radiation angle is rather broad. Even the illuminating horn is an upright rectangle that helps establish a narrow horizontal angle and a wider vertical angle.

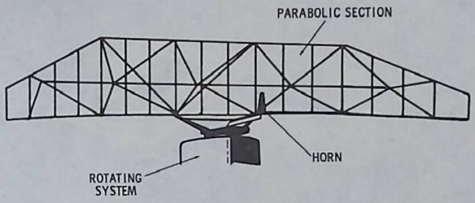


Fig. 2-38. Parabolic section and rectangular horn illuminator.

The antenna style of Fig. 2-39 is adaptable to marine radar, and it is referred to as a *pillbox*. The pillbox is a parabolic section positioned between two metal plates. The separation between the two plates can be somewhat less than one wavelength. The waveguide directs energy into the pillbox slot; the energy is then reflected from the parabolically shaped rear wall into a narrow horizontal beam. The vertical beam is rather broad, as is required for many practical radar applications.

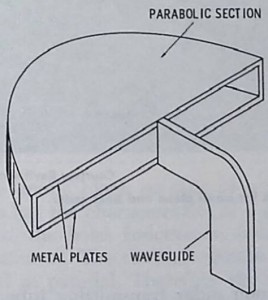
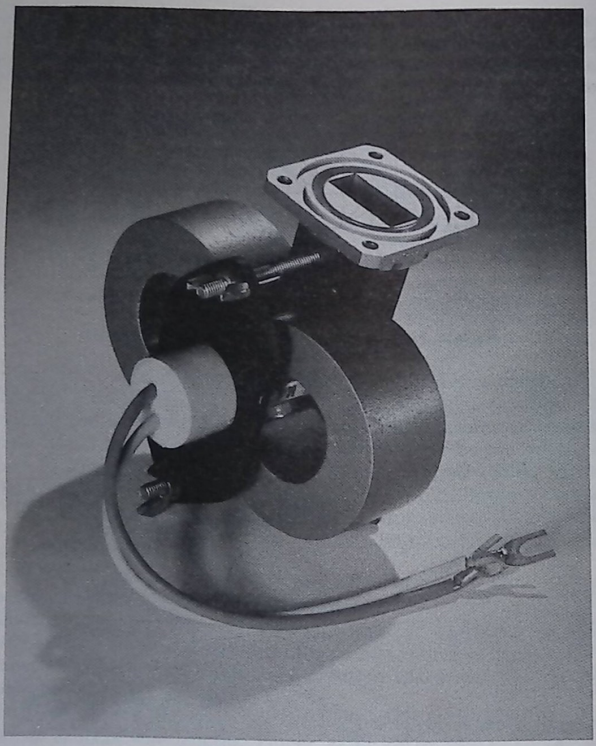


Fig. 2-39. Basic pillbox antenna.

SPECIAL TUBES

Conventional tubes and/or transistors can be used throughout most of the circuits of a radar set. However, there is a need for several special tube types. The FCC examination contains a number of questions on these special types that are used in radar sets.



Courtesy Raytheon Co.

Fig. 2-40. Low-powered magnetron for small plane and boat radar.

Magnetron

The magnetron is the most common radar transmitting tube. It is used almost exclusively in marine radar installations. Klystrons are sometimes used for extremely high-powered search-radar installations. The magnetron is a self-contained oscillator and requires only a means of input power application and rf microwave energy removal. Essential parts (Figs. 2-40 and 2-41) are the anode block and cathode mounted in an evacuated envelope, external magnet, and means for applying fil-

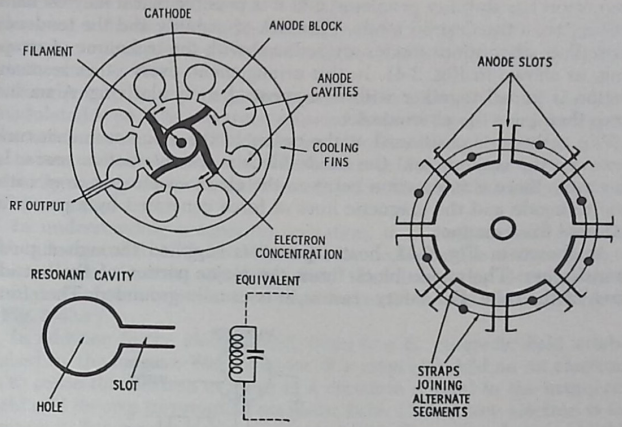


Fig. 2-41. Magnetron construction and principle.

ament power and removing microwave energy. Following are some typical electrical data:

Heater Voltage	5.0 Volts
Heater Current	0.65 Ampere
Pulse Duration	0.2 μs
Duty Cycle	0.0003
Peak Anode Voltage	5.0 Kilovolts
Peak Anode Current	3.5 Amperes
Peak Power Output	5.0 Kilowatts
Frequency	9410 $\pm$ 50 MHz
Life	500 Hrs Min

The anode block consists of a series of resonant cavities, each of which has the characteristics of a parallel resonant circuit. In approximation, the holes function as inductances, and the slots function as capacitances. The cavities operate as individual resonant circuits connected in parallel. Therefore the total capacitance of the magnetron oscillator is nC (n = number of cavities), while the total inductance is L/n. Inasmuch as the resonant frequency of the magnetron varies inversely with the square root of the LC product, the frequency of the magnetron oscillator is the same as the resonant frequency of each individual cavity.

The multicavity arrangement and the unavoidable mutual coupling between cavities means that there are other resonant modes. Thus the

magnetron has stability problems, and it is possible that it may oscillate at other than the desired mode. This lack of stability and the tendency to oscillate at spurious modes are reduced with the technique of strapping, as shown in Fig. 2-41. In this arrangement, every other resonant section is joined together with a segment of a circular ring. A second strap then joins the alternate set.

The cathode is positioned at the center of the magnetron structure. Between the cathode and the anode block is the *interaction space.* In this area, there is interaction between the electrons moving from cathode to anode and the magnetic lines of force generated by a powerful external fixed magnet.

As shown in Fig. 2-42, heater power is supplied through a pulse transformer. The anode block forms the major portion of the outside area of the tube. For safety reasons, it is usually grounded. Therefore,

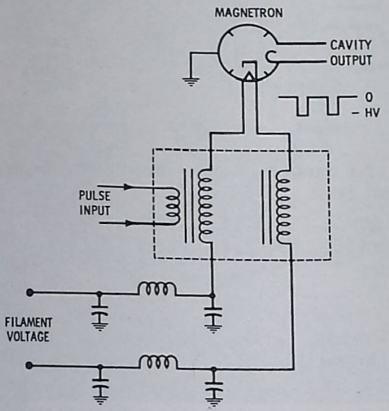


Fig. 2-42. Magnetron circuit.

in pulsing the magnetron oscillator, it is necessary to use a pulse of a high negative amplitude which is applied to the cathode. Inasmuch as the anode operates at ground potential, the cathode and filament circuits must be designed to withstand a high negative potential. The filament chokes and transformer isolate the filament source from the pulse circuit.

Most magnetrons are fixed-tuned, with the frequency being determined by the physical dimensions of the cavity. Some slight change in frequency can be accomplished by varying the load into which the magnetron operates. Magnetrons can be tuned by mechanical means

with the use of a bellows or a threaded arrangement. A frequency-changing inductive element can be made to move into the individual cavities, or a capacitive element can be inserted into the individual cavity slots.

Fundamentally, the magnetron oscillator is a transit-time or velocity-modulated type. The electrons released from the cathode come under the influence of various fields during the time that they are in transit between cathode and anode. These various fields cause a change in velocity among electrons and cause them to bunch as they come closer to the anode.

In understanding magnetron operation, it is necessary to consider the influence of three fields. When the anode is positive with respect to the cathode, there is an electric field that draws the electrons in a straight-line path between the cylindrical cathode and the anode block (Fig. 2-43A).

In addition to the electric field, there is a dc magnetic field established by the magnet. The influence of a magnetic field on an electron is to cause the electron to move in a direction normal to the magnetic field and its own surrounding magnetic field. (When any electron is in motion, it has a surrounding magnetic field.) Thus, the electron would

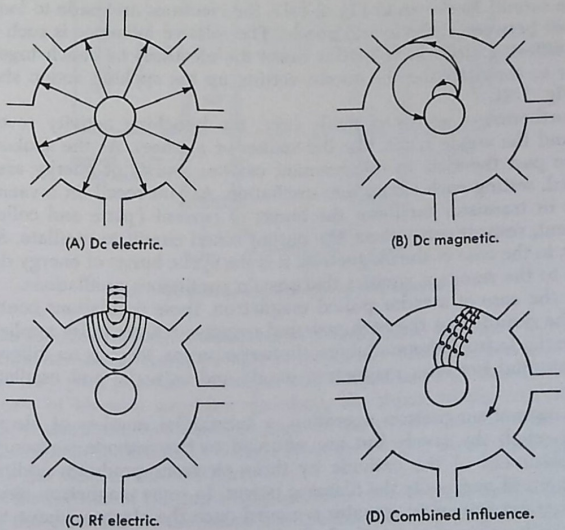


Fig. 2-43. Influence of three fields on electron motion.

have a tendency to revolve in a circle were it not for the combined influence of the electric and magnetic fields, as shown in Fig. 2-43B. When the magnetic field is strong, it is dominant; thus when the electron leaves the cathode, it is turned around in a rather tight circle, returning to the cathode surface. For a somewhat weaker magnetic field, the electron would continue to return to the cathode, but over a longer path. With a magnetic field of proper magnitude, the electron has sufficient velocity, under the influence of the combined fields, to reach the anode block over a curved path.

In addition to the dc electric and dc magnetic fields, there is a radio-frequency (microwave) field which extends outward from the cavity slot, as shown in Fig. 2-43C. This is a fast-changing oscillating field that corresponds to the resonant frequency of the cavities.

As in the start of any type of oscillator, a finite time is required for the buildup. In the case of the magnetron oscillator, any slight discontinuity in electron flow becomes the catalyst that initiates the buildup of oscillations. The influence of the resultant rf fields is pronounced; they cause the electron velocities to build up and slow down. The relative influence the field exerts depends on the position from which a given electron leaves the cathode surface relative to the phase of the changing field. Thus, the rf field does not influence each electron to the same extent. As shown in Fig. 2-43D, the electrons are made to loop in transit between cathode and anode. The relative influence is such that the differing electron velocities cause the electrons to bunch together prior to their striking the anode, setting up the spoking action shown in Fig. 2-41.

Furthermore, as the rf fields vary, the bunching activity revolves around the anode block like the spokes of a wheel. As the spokes revolve past the slots in the resonant cavities, bursts of energy are released, setting each cavity into oscillation. As you recall, in a vacuum-tube or transistor oscillator the bursts of current (plate and collector current, respectively) cause the output tuned circuit to oscillate. Similarly, in the case of the magnetron, it is the cyclic bursts of energy delivered to the resonant cavities that sustain continuous oscillations.

In the case of a radar pulsed magnetron, these oscillations continue for the duration of the high-powered negative trigger pulse applied to the cathode from the modulator. Between pulses, there is no difference of potential between magnetron anode and cathode, and oscillations cease.

In normal magnetron operation, a substantial number of electrons never reach the anode but are returned to the cathode surface. The bombardment of the cathode by these electrons produces additional heating and augments the filament power. In some magnetron circuits, the filament power is actually removed once the electrons have taken over the heating of the cathode surface.

Klystron

The klystron is also a transit-time or velocity-modulated tube. It is a popular type of local oscillator for radar receivers. Klystrons are available with two resonant cavities or with a single resonant cavity. Klystron local oscillators are dominantly of the single-cavity type. However, we will first consider a two-cavity type because its operation can be more readily understood.

As shown in Fig. 2-44, the klystron consists of a cathode, accelerator grid, anode, and collector. With no voltages applied to the cavities, the electrons would move in a continuous stream from cathode to collector. In operation, it is the cavity-voltage variations that influence the electrons in transit between cathode and collector.

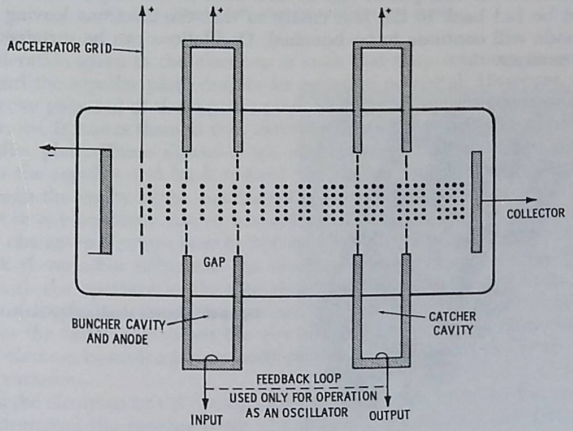


Fig. 2-44. Basic principle of a two-cavity klystron.

The electrons are first focused into a fine beam, and they pass into the *buncher cavity* through a hole in the anode. The electrons are acted on as they pass between the input and output sides of this cavity. In the case of klystron amplifier operation, the signal to the amplifier is applied across the two sides, or gap, of the cavity. In the case of an oscillator, it is the feedback voltage from the output cavity that appears across the sides of the first cavity.

As the far side of the gap swings positive with respect to the cathode side, the electrons in the beam are speeded up. During the negative alternation of the microwave signal, the far side of the gap is negative

with respect to the input side; consequently the electron velocity is slowed. It is apparent that as the microwave signal goes through its sinusoidal cycle at the first cavity, there is a like change in electron velocity. In effect, the electron stream has been velocity modulated.

The electrons pass with differing velocities through the exit side into the *drift* or *bunching* area. Inasmuch as they leave with differing velocities, the fast-moving electrons now have sufficient time to catch up to the slower-moving ones. Some of the very slow-moving electrons now fall back to the next group of fast-moving electrons.

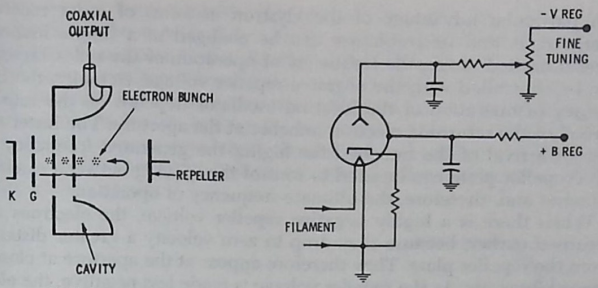
From the preceding, it can be seen that although the electrons left the cathode at a uniform velocity, they now bunch together, as shown in Fig. 2-44. The electrons now pass the output-cavity gap in bunches. They deliver energy to that cavity at a cyclic rate, setting it into oscillation. Most of this power can be delivered to the output. Some of it must be fed back to the first cavity so that the electrons leaving the cathode will continue to be bunched. Oscillations can be sustained in this manner.

Courtesy Raytheon Co.

Fig. 2-45. Klystron single-cavity oscillator.

A single-cavity reflex klystron is shown in Figs. 2-45 and 2-46. The reflex klystron has only a single cavity, but a *repeller* electrode or plate has been added. This electrode is operated at a negative potential with respect to the cathode.

An electron gun arrangement again acts as a source of electrons, directing them as a beam into the aperture area of the cavity. The



(A) Klystron construction. (B) Circuit.

Fig. 2-46. Single-cavity klystron oscillator and circuit.

acceleration given to the electrons is such that they continue to move toward the repeller plate despite its negative potential. However, the negative potential of the repeller plate has a retarding influence on the electrons. It causes them to slow down to zero velocity just ahead of the repeller plate. These slowed-down electrons are then attracted away from the repeller and back toward the positive gun area. They pass through the cavity again, but traveling in the opposite direction.

As in any oscillator circuit, a small variation will produce the necessary change in electron flow to initiate the buildup of oscillations. This weak rf variation influences the electrons of the beam as they pass through the aperture in the direction of the repeller plate. As in the case of the first cavity of the two-cavity klystron, the voltage variation across the cavity gap causes the electrons to speed up and slow down. The electron beam is again velocity modulated according to the rf voltage variation.

As the electrons travel through the bunching area between the cavity aperture and the repeller plate, the differing velocities cause them to arrive in bunches in front of the repeller plate.

The negative repeller reverses the direction of electron flow and causes the electrons to pass the gap again going in the opposite direction. Each bunch delivers energy to the resonant cavity, and in this manner, oscillations are sustained. Of course, the resonant variations in the cavity are strong, and some energy can be withdrawn through a pickup loop or cavity output. Some energy must remain in the cavity to make certain that electrons leaving the gun continue to be bunched as they move toward the repeller.

It is apparent that the turn-about activity of the repeller plate permits the single cavity of the reflex klystron to act as both the ouput tank circuit and the buncher cavity.

A particular advantage of the klystron in terms of radar receiver operation is that its frequency can be changed in a simple manner. Over a limited range, the frequency of operation of the reflex klystron can be controlled with the negative repeller voltage. Actually, the frequency of operation of the klystron oscillator depends on the rate of arrival of the returning electron bunches at the aperture. The faster the rate of arrival of the bunches, the higher the generated frequency is. The repeller plate can be used to control the spacing between electron bunches and, therefore, the ultimate frequency of operation.

When there is a highly negative repeller voltage, the electrons are returned earlier, because they drop to zero velocity a greater distance from the repeller plate. They therefore appear at the aperture at closely spaced intervals. As the repeller voltage is made less negative, the electron bunches travel a greater distance and come closer to the repeller before they are turned around. As a result, they are more widely spaced, and their rate of arrival at the aperture is slowed; hence, a lower frequency of oscillation occurs.

As mentioned previously, radar systems often use an afc system so that there might be a constant frequency difference between the transmitted frequency and the local-oscillator frequency. This difference frequency must match the i-f frequency for optimum receiver performance. The afc system of a radar receiver compares the magnetron and klystron frequencies and develops a dc error voltage that is applied to the repeller plate. Inasmuch as the repeller plate determines the klystron-oscillator frequency, any change in the transmitted frequency produces a corresponding change in the klystron local-oscillator frequency, thereby maintaining an exact frequency difference despite any drift in frequency of the magnetron oscillator.

TR and ATR Tubes

The tr and atr tubes are a part of the duplexer described previously. The tr tube protects the receiver during the transmitted pulse, and the atr tube minimizes echo signal loss in the transmitter channel during reception. Both tubes are gas-filled and contain two electrodes. The strong transmitter pulse ionizes the gas and causes a low-resistance arc to develop between the two electrodes. In this condition, the tr and atr tubes represent microwave-frequency short-circuits.

Usually these tubes are mounted in a cavity, and therefore the continuity of the waveguide or coaxial-line system of the duplexer is maintained. They must also be positioned correctly to reflect the proper impedance to key points in the duplexer.

A typical duplexer and tr and atr mounting positions are shown in Fig. 2-47. The transmitter output sees a direct waveguide path through the duplexer to the antenna. In the receiving channel, the tr tube is mounted exactly one-quarter wavelength down from the T-junction

connection to the waveguide. The transmitter pulse fires the tr tube. Inasmuch as the tr tube then acts as a microwave short, it reflects a maximum impedance to the junction point. Therefore, the transmitter pulse sees a maximum impedance in the direction of the receiver. It does not enter the receiver channel but passes on to the antenna.

The atr tube is also fired by the transmitter pulse. It reflects a high impedance (quarter wavelength shorted) to its junction with the transmitting path. Therefore, it does not impede the transmission of the pulse to the antenna.

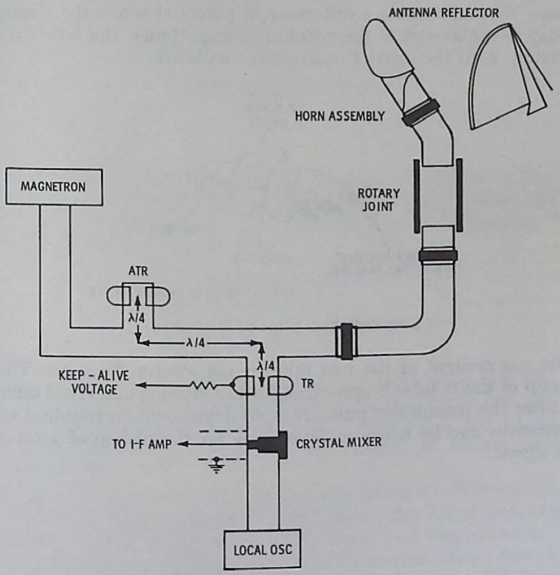


Fig. 2-47. Duplexer and antenna feed arrangement.

The atr tube performs its major task in the receiving operation. When the transmitter pulse is off and the receiver is listening, neither the tr tube nor the atr tube is conducting. With the tr tube nonconducting, there is no opposition to the flow of signal into the receiver. Since the atr tube is also open and is exactly one-half wavelength away from the entrance to the receiving channel, it reflects a high impedance to this point. Thus an incoming signal sees a high impedance looking toward

the magnetron, and it does not enter the transmitter channel. Rather it follows the low-impedance path to the receiver input.

The tr and atr tubes (Fig. 2-48) are quite similar except for a facility for applying a *keep-alive voltage* to the tr tube. This is a negative voltage applied to the cathode of the tr tube. In a radar system, it is important that the receiver input be blocked very quickly with the initiation of the transmitter pulse. In this way, the receiver detector and other components are not burned out or relegated to a short operational life. If this is to be accomplished, the tr tube must fire instantly at the start of the transmitter pulse. The fast firing is ensured by the keep-alive voltage. By maintaining a difference of potential across the electrodes, the gap is set almost to the point of arcing. Hence, the tube fires immediately with the start of magnetron oscillation.

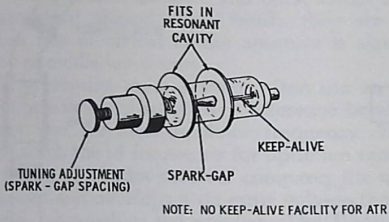


Fig. 2-48. Basic tr and atr construction.

The gas content of the two tubes is not always the same. The gas makeup of the tr tube is optimized for fast starting and rapid deionization after the transmitter pulse. A rapid deionization is required so that the receiver can be made ready quickly for the pickup of a returning echo signal.

CHAPTER 3

Laws and Operating Practice, Elements 1 and 2

In the chapters that follow, specific answers are given to the FCC study-guide questions given in the publication *Study Guide and Reference Material for Commercial Radio Operator Examinations.* These are arranged in the following order:

Chapter 3: Elements 1 and 2
Chapter 4: Element 5
Chapters 5 through 14: Element 6
Chapter 15: Element 8

Each radio operator must be familiar with basic radio law and must know proper operating practice. Element 1 covers basic law and consists of twenty multiple-choice questions. Element 2 has to do with basic operating practice. This test, too, consists of twenty multiple-choice questions.

Appropriate references are given in parentheses following many of the answers. In these references, "RR" means the listed paragraph or paragraphs may be found in the FCC Rules and Regulations. "SEC" indicates the reference is a section of the Communications Act of 1934, as amended. "ART" refers to an article in the International Telecommunication Convention, Atlantic City, 1947 or the International Radio Regulations (Atlantic City, 1947). (See Appendix I and Appendix II.) "Summary" refers to the summary of operating practice given later in this chapter.

ELEMENT 1—BASIC LAW

1. Where and how is an operator license or permit obtained?—Request an application form and examination schedule from the nearest FCC field office. Submit the application in the prescribed form, including all subsidiary forms and

documents accompanied by the prescribed fee, properly completed and signed, in person or by mail, to the office of your choice (usually the closest one). This office will make the final arrangements. (RR 13.11a)

2. When a licensee qualifies for a higher grade of FCC license or permit, what happens to the lesser grade license?—The license or permit held will be cancelled upon issuance of the new license. (RR 13.26)

3. Who may apply for an FCC license?—Normally, commercial licenses are issued only to citizens of the United States. (RR 13.5a)

4. If a license or permit is lost, what action must be taken by the operator?—The commission must be notified immediately, and a properly executed application for a duplicate should be submitted. A statement must be included regarding the circumstances involved in the loss of the license. The operator must exhibit in lieu of the original document a signed copy of the submitted application. (RR 13.71 and 13.72)

5. What is the usual term for radio operators?—Five years. (RR 13.4a)

6. What government agency inspects radio stations in the United States?—The Federal Communications Commission. (SEC 303n)

7. When may a license be renewed?—The application may be filed at any time during the final year of the license term or during a one-year period after the date of the expiration of the license. During this one-year grace period any prior license is not valid. (RR 13.11a)

8. Who keeps the station log?—The person or persons competent to do so having actual knowledge of the facts required. They shall sign the appropriate log when starting duty and again when going off duty (RR 73.111)

9. Who corrects errors in the station log?—Only the person originating the entry. (RR 73.111)

10. How may errors in the station log be corrected?—The person originating the entry shall strike out the erroneous portion, initial the correction made, and indicate the date of correction. (RR 73.111)

11. Under what conditions may messages be rebroadcast?—Only by the express authority of the originating station. (SEC 325a)

12. What messages and signals may not be transmitted?—Unnecessary, unidentified, or superfluous communications; obscenity, indecency, profanity, and false signals using any call or signal which has not been assigned by proper authority to the radio station concerned. (RR 13.66, 13.67, and 13.68)

13. May an operator deliberately interfere with any communication or signal?—No. (RR 13.69)

14. What type of communication has top priority in the mobile service?—Distress calls, distress messages, and distress traffic. (ART 37)

15. What are the grounds for suspension of an operator's license?—Violation of any provision of any act, treaty, or convention binding on the United States; failure to carry out a lawful order of the master or person lawfully in charge of ship or aircraft on which he is employed; damaging or permitting the damage of any radio apparatus or installation; transmission of profane or obscene language, false or deceptive signals, or call signals or letters which have not been assigned to the station in operation; willful or malicious interference with other radiocommunications or frequencies; obtaining, attempting to obtain, an operator's license by fraudulent means. (SEC 303m)

16. When may an operator divulge the contents of an intercepted message?—He may divulge the contents of any radio-communications broadcast or transmission by others for use of the general public or relating to ships in distress. (SEC 605)

17. If a licensee is notified that he has violated an FCC rule or provision of the Communications Act of 1934, what must he do?—He must reply within ten days to the office of the commission originating the official notice. The answer to each notice shall be complete in itself and shall not be abbreviated by reference to other communications or other notices. In every instance the answer shall contain a statement of the action

taken to correct the condition or omission complained of, and to preclude its recurrence. Information concerning equipment of concern, and name and license number of operator in charge. (RR 1.89)

18. If a licensee receives a notice of suspension of his license, what must he do?—No order of suspension of any operator's license shall take effect until 15 days after a notice in writing of the cause has been given to the operator. He may make written application to the commission at any time within said 15 days for a hearing upon such order. If, after a hearing, a license is ordered suspended, the operator shall send his license to the office of the Commission in Washington, D.C., on or before the effective date of such order. (RR 1.85)

19. What are the penalties provided for violation of the provisions of the Communications Act of 1934 or a rule of the FCC?—Penalties for violation of the Act provide for a fine of not more than $10,000 or imprisonment for a term not exceeding one year, or both. The penalty provided for violation of FCC rules is a fine of not more than five hundred dollars ($500) for every day during which said offense occurs. (SEC 501 and 502)

20. Define harmful interference.—Any emission, radiation, or induction which endangers the function of a radionavigation service or other station services, or seriously degrades, obstructs, or repeatedly interrupts a radiocommunications service operating in accordance with the regulations.

ELEMENT 2—BASIC OPERATING PRACTICE

Each operator should know and abide by the rules and accepted procedures of operation. Courtesy and consideration are two very important factors in minimizing unnecessary interference and maintaining reliable communications on active channels. The license holder should be an example to operators of lower grade, and he should do everything possible to encourage proper operations in the service or services with which he is concerned.

Summary of Operating Practice

A fine summary of radiotelephone operating practice, recommended by the FCC, follows. This summary should prove helpful in preparing for examination element 2.

A licensed radio operator should remember that the station he desires to operate should be licensed by the FCC. In order to prevent interference and to give others an opportunity to use the airways, he should avoid unnecessary calls and communications by radio. He should remember that radio signals normally travel outward from the transmitting station in many directions, and therefore these transmitted signals could be intercepted by unauthorized persons.

Before making a radio call, the operator should listen on the communications channel to ensure that interference will not be caused to communications which may already be in progress. At all times in radiocommunications, the operator should be courteous.

Station identification should be made clearly and distinctly so as to avoid unnecessary repetition of call letters and enable other stations to identify all calls clearly.

An operator normally exhibits his authority to operate a station by posting a valid operator license or permit at the transmitter control point.

While a radio transmitter is in a public place, it should at all times be either attended by or supervised by a licensed operator; or the transmitter should be made inaccessible to unauthorized persons.

A radio transmitter should not be on the air except when signals are being transmitted. The operator of a radiotelephone station should not press the push-to-talk button, except when he intends to speak into the microphone. Radiation from a transmitter may cause interference even when voice is not transmitted.

When radiocommunications at a station are unreliable or disrupted due to static or fading, it is not a good practice for the operator to continuously call other stations in attempting to make contact, because his calls may cause interference to other stations that are not experiencing static or fading.

A radiotelephone operator should make an effort to train his voice for most effective radiocommunication. His voice should be loud enough to be distinctly heard by the receiving operator, and it should not be too loud, since it may become distorted and difficult to understand at the receiving station. He should articulate his words and avoid speaking in a monotone as much as possible. The working range of the transmitter is affected to some extent by the loudness of the speaker's voice. If the voice is too low, the maximum range of the transmitter cannot be attained; if the voice is too loud, the range may be reduced to zero due to the signals becoming distorted beyond intelligibility. In noisy locations the operator sometimes cups his hands over the microphone to exclude extraneous noise. Normally, the microphone is held from 2 to 6 inches from the operator's lips.

It is important in radiotelephone communications that operators use familiar and well-known words and phrases in order to ensure accuracy and eliminate undue repetition of words. Some radio operating companies, services, networks, associations, etc., select and adopt standard procedure words and phrases for expediting and clarifying radiotelephone conversations. For example, in some services, "Roger" means "I have received all of your last transmission," "Wilco" means 'Your last message received, understood, and will be complied with," "Out" or "Clear" means "This conversation is ended and no response is expected," "Over" means "My transmission is ended, and I expect a response from you," "Speak slower" means "Speak slowly," "Say Again" means "Repeat," and "Words twice" means "Give every phrase twice."

Often in radiotelephone communications a "phonetic alphabet" or word list is useful in identifying letters or words that may sound like other letters or words of different meaning. For example "group" may sound like "scoop," or "bridge" may sound like "ridge." A phonetic al-

phabet or word list consists of a list of 26 words, each word beginning with a different letter for identifying that particular letter. If the letters in "Group" are represented in a phonetic alphabet by George, Roger, Oboe, Uncle, and Peter, the word "Group" is transmitted as "Group, G as in George, R as in Roger, O as in Oboe, U as in Uncle, P as in Peter."

In making a call by radio, the call sign or name of the called station is generally given 3 times followed by the call letters of the calling station given 3 times.

In testing a radiotelephone transmitter, the operator should clearly indicate that he is testing, and the station call sign or name of the station, as required by the rules, should be clearly given. Tests should be as brief as possible.

If a radio station is used only for occasional calls, it is a good practice to test the station regularly. Regular tests may reveal defects or faults which, if corrected immediately, may prevent delays when communications are necessary. Caution should be observed by persons testing a station to make certain their test message will not interfere with other communications in progress on the same channel. Technical repairs or adjustments to radiotelephone communication stations are made only by or under the immediate supervision and responsibility of operators holding first- or second-class licenses.

When a licensed operator in charge of a radiotelephone station permits another person to use the microphone and talk over the facilities of the station, he should remember that he continues to bear responsibility for the proper operation of the station.

If an operator wishes to determine the specifications for obstruction marking and lighting of antenna towers, he should look in Part 17 of the Rules and Regulations of the FCC. If he wishes to determine the specifications for a particular station, he should examine the station authorization issued by the Commission.

Radiotelegraph practice is covered in Chapter 4.

General (Series "O")

1. What should an operator do when he leaves a transmitter unattended?—The transmitter should be made inaccessible to unauthorized persons.

2. What are the meanings of clear, out, over, roger, words twice, repeat, and break?—Refer to the appropriate words in the summary. "Repeat" means to transmit message or section of message again to make certain it has been copied correctly. "Break" means that the transmitting station will pause briefly for an acknowledgement from the station copying his message, or that the receiving station wishes to break in on the transmitting station to request a repeat.

3. How should a microphone be treated when used in noisy locations?—The operator can cup his hand over the microphone to exclude extraneous noise.

4. What may happen to the received signal when an operator has shouted into a microphone?—The range of the transmission may be decreased, because the signal may become distorted beyond intelligibility.

5. Why should radio transmitters be off when signals are not being transmitted?—Radiation from the transmitter may cause interference even though voice or

other information is not being transmitted.

6. Why should an operator use well-known words and phrases?—It is advisable to ensure accuracy and save time from undue repetition of words.

7. Why is the station call sign transmitted?—So that other stations may clearly identify all calls. Call signs must also be given at prescribed times according to the FCC Rules related to the particular radio service.

8. Where does an operator find specifications for obstruction marking and lighting where required for the antenna towers of a particular radio station?—Data may be found in Part 17 of the FCC Rules and Regulations and in the station authorization.

9. What should an operator do if he hears profanity being used at his station?—He should take steps to prevent the profanity from going out on the air.

10. When may an operator use a station without regard to certain provisions of the station's license?—In a period of emergency during which normal communications are disrupted. (RR 2.405)

11. Who bears the responsibility if an operator permits an unlicensed person to speak over his station?—The licensed operator continues to bear responsibility for the proper operation of the station.

12. What is meant by a phonetic alphabet in radiotelephone communications?—It is a list of words helpful in identifying letters or words that may sound like other letters or words that have different meanings.

13. How does the licensed operator of a station normally exhibit his authority to operate the station?—A valid operator license must be displayed at the transmitter control point.

14. What precautions should be observed when you are testing a station on the air?—Be certain testing does not interfere with other communications in progress on the same channel. Clearly indicate that you are testing. *Technical repairs and adjustments* are the responsibility of the holder of a first- or second-class license.

Maritime (Series "M")

M1. What is the importance of the frequency 2182 kHz?—This frequency is the international distress frequency for radiotelephony. It can be used by ships, aircraft, and survival craft using frequencies in the 1605- to 3500-kHz spectrum. This frequency is also the international general radiotelephone calling frequency for the maritime mobile service. It may be used by ship stations and aircraft stations operating in the maritime mobile service. (RR 83.352, 83.353a)

M2. Describe completely what action should be taken by a radio operator who hears a distress message; a safety message.—If he is in the vicinity beyond any possible doubt, the operator should immediately acknowledge receipt. However, in areas where reliable communication with one or more coast stations are practicable, a ship station may defer this acknowledgement for a short interval so that a coast station may acknowledge receipt. If not in the vicinity beyond any possible doubt, the operator shall allow a short interval of time to elapse before acknowledging receipt of the message in order to permit stations nearer to the mobile station in distress to acknowledge receipt of the message without interference.

The acknowledgement of the receipt of a distress message is then made according to established radiotelegraph and radiotelephone operating procedures. On order of the master or person responsible for the ship he is on, the operator shall supply the name of his ship and position and the speed at which it is proceeding toward, and the approximate time it will take to reach the station in distress. However, it is important that the station shall be certain that it will not interfere with the emission of other stations better situated to render immediate assistance to the station in distress.

A station may relay the distress message in any of the following cases: (1) station in distress is not able to transmit a distress message, (2) when a respon-

sible person considers that further help is necessary, (3) when the station is not in position to render assistance but has heard that the distress message has not been acknowledged. Read RR 83.240, 83.241, and 83.242 carefully.

A safety signal indicates that the station is about to transmit a message concerning the safety of navigation or giving important meteorological warning. This station should be given proper priority of transmission. (RR 83.239, 83.240, 83.241, 83.242, 83.249 and ART 38)

M3. What information must be contained in distress messages? What procedure should be followed by a radio operator in sending a distress message? What is a good choice of words to be used in sending a distress message?—A distress message should contain the following information:

A. Distress call.
B. Name of ship.
C. Geographical position.
D. Nature of distress.
E. What kind of assistance is needed.
F. Any additional information that will help in the rescue, such as type of ship, color, length, etc.

The international radiotelegraph distress signal is S O S (. . . – – – . . .); the international radiotelephone distress signal is the word "MAYDAY." The radiotelephone distress procedure shall consist of a radiotelephone alarm signal whenever possible, the distress call, and the distress message. This distress transmission shall be made slowly and distinctly, each word being clearly pronounced. Words should be simple and to the point. On advisement, it may be necessary to transmit suitable signals followed by call sign or name to permit direction-finding stations to determine position.

The distress message can be repeated at intervals until an answer is received. If there are no answers, the message may be repeated on any other available frequency on which attention might be attracted.

It is important that you go over each rule and regulation very carefully, word by word. (RR 83.234 and 83.238)

M4. What are the requirements for keeping watch on 2182 kHz? If a radio operator is required to stand watch on an international distress frequency, when may he stop listening?—Each station on board a ship navigating the Great Lakes and licensed to transmit on telephony within the band 1600 to 3500 kHz shall maintain an efficient watch on 2182 kHz, whenever the station is not being used for transmission on that channel or for communications on other radio channels. Except for stations on board vessels required by law to be fitted with radiotelegraph equipment, each ship station licensed to transmit telephony within the band 1600 to 3500 kHz shall maintain an efficient 2182-kHz watch whenever such station is not being used for transmission on that channel or for communication on other radio channels. (RR 83.223)

M5. Under what circumstances may a coast station contact a land station by radio?—To facilitate the transmission or reception of safety communications to or from a ship or aircraft station. (RR 81.302a2)

M6. What do distress, safety, and urgency signals indicate? What are the international urgency, safety, and distress signals? In the case of a mobile radio station in distress, what station is responsible for the control of distress-message traffic?—A distress signal indicates that a mobile station is threatened by grave and imminent danger and requests immediate assistance. The urgency signal indicates that the calling station has a very urgent message to transmit concerning the safety of a ship, aircraft, or other vehicle, or the safety of a person. The safety signal indicates that the station is about to transmit a message concerning the safety of navigation or giving important meteorological warning. These signals are as follows:

	Radio-telegraph	Radio-telephone
Distress	S O S	MAYDAY
Urgency	X X X	PAN
Safety	T T T	SECURITY

Whenever possible, the mobile station in distress is responsible for the control

of distress-message traffic. (RR 83.234 through 83.249)

M7. In regions of heavy traffic, why should an interval be left between radiotelephone calls? Why should a radio operator listen before transmitting on a shared channel? How long may a radio operator in the mobile service continue attempting to contact a station which does not answer?—An interval should be left between radiotelephone calls to permit the shared use of the channel. An operator should listen before transmitting on a shared channel to make certain that he does not interfere with communications in progress. A call shall not continue for more than 30 seconds. If the called station does not reply, a second call should not be made until after an interval of two minutes. If there is no reply to a call sent three times at intervals of two minutes, the calling shall cease and shall not be renewed until after an interval of fifteen minutes. However, if there is no reason to believe that harmful interference will be caused, the call sent three times at intervals of two minutes may be repeated after a pause of not less than three minutes. (Summary.)

M8. Why are test transmissions sent? How often should they be sent? What is the proper way to send a test message? How often should the station call sign be sent?—If the station is used at infrequent intervals, test transmissions can be sent out to ascertain if the transmitter continues to operate in a normal manner. If the station has not been in operation, the transmitter can be checked with a test transmission according to an adopted schedule (once each 24 hours is often considered appropriate). When tests are required, precautions should be taken to prevent any emission that will cause harmful interference. Radiation must be reduced to the lowest practicable value and entirely suppressed if possible. The licensed operator shall listen carefully before test emissions so as not to interfere with a transmission in progress.

The official call sign of the testing station followed by the word "test" shall be announced as a warning that test emissions are to be made. If any other station transmits the word "wait," testing shall be suspended an appropriate interval of time.

During tests the operator then announces the word "test" followed by a voice transmission test by numerical count. Test signals should be transmitted that do not conflict with normal operating signals or that will actuate automatic alarms. The test signal shall have a duration not exceeding 10 seconds.

At the conclusion of the test, a voice announcement of the official call sign, name of the ship or station, and general location is to be made. It is customary to give the call sign three times. The test transmission shall not be repeated until at least one minute has elapsed, or, in a region of heavy traffic, a period of at least five minutes shall elapse before another test transmission is made on key frequencies. (Summary)

M9. In the mobile service, why should radiotelephone messages be as brief as possible?—Transmissions should be brief to give other stations a chance to use the channel and to minimize interference. (Summary)

M10. What are the meaning of: clear, out, over, roger, words twice, repeat, and break?—Refer to the summary of operating practice.

M11. Does the Geneva 1959 treaty give other countries the authority to inspect US vessels?—Yes, when the mobile station visits another country. The license or a copy certified by the authority which has issued it should be permanently exhibited in the station. (ART 21)

M12. Why are call signs sent? Why should they be sent clearly and distinctly?—Call signs should be sent and transmitted clearly and distinctly so that the station may be identified exactly by other stations and transmission time kept to a minimum. (Summary)

M13. How does the licensed operator of a ship's station exhibit his authority to operate a station?—The original license should be exhibited at a conspicuous place at the principal location on board ship. For certain stations of a por

table nature and when the operator holds a restricted radiotelephone operator permit, the person may have on his person either the operator license or a verification card. (RR 83.165)

M14. When may a code station not charge for messages it is requested to handle?—No charge shall be made for the transmission of distress messages and replies thereto in connection with situations involving the safety of life and property at sea, or for any information concerning danger to navigation as designated. Except for effective tariffs on file with the commission, no charge shall be made for the service of any public coast station. (RR 81.179 and 83.271)

M15. What is the difference between calling and working frequencies?—Calling frequencies are used for transmissions from a station solely to secure the attention of another station for a particular purpose. A working frequency is used strictly for carrying on radiocommunications for a purpose other than calling by any station or stations using telegraphy, telephony, or facsimile. (RR 83.6)

CHAPTER 4

Radiotelegraph Operating Practice, Element 5

Each radiotelegraph operator must be familiar with international and national laws, regulations, and procedures related to radiotelegraph operations. In particular, he must be thoroughly knowledgeable concerning distress, urgency, and safety traffic. He must know how to handle public correspondence and be familiar with various abbreviations and traffic forms. Element 5 of the FCC license examination consists of 50 multiple-choice questions.

SUMMARY OF GOOD OPERATING PRACTICE

A fine FCC summary of good operating practice follows:

Radiotelegraph operating procedures and practices differ in many respects from those of radiotelephony. In radiotelephony, conversations are generally carried on in an informal manner similar to speaking on a wire telephone line, whereas in radiotelegraphy, messages are generally formally written in advance of transmission. Generally, the structure of a message consists of the preamble, the address, the text, and the signature. The radio operator prepares the preamble, while the other parts are supplied by the sender of the message.

The preamble usually contains a prefix which indicates the type of message, charge rate classification, and priority. The preamble also contains the daily serial number of the message, word count or check, place of origin, time and date of filing, and instructions for routing the message. The address of the radiotelegram indicates to whom the message is to be delivered. The text of the message contains the information that the sender wishes to convey to the recipient of the message. The signature gives the name of the person who filed the message.

Sometimes, for security reasons, radiotelegraph messages are written in code or cipher language. In code language, the message is often sent in groups of four or five numbers or letters of no apparent meaning, but which can be decoded by the recipient of the message. Cipher language is composed of figures, words, names, or combinations of letters of no apparent meaning but which can be deciphered by the recipient of the message.

In radiotelegraphy as well as in radiotelephony, the calling station normally gives the call sign of the station three times followed by the call sign of the calling station three times. For example, if KABC calls WDEF, the call would be made as:

WDEF WDEF WDEF DE KABC KABC KABC K

WDEF answers:

KABC KABC KABC DE WDEF WDEF WDEF R K

The International Morse Code is used by most radiotelegraph stations. The code is transmitted either by hand or by automatic devices. When the code is transmitted by hand, either a Morse hand key is used or a semiautomatic key, or "bug," is used. Some stations do use teletypewriter machines employing special telegraph signals.

When hand or semiautomatic telegraph keys are used, the speed of transmission varies from approximately 10 to 40 words per minute, depending upon the proficiency of the operators.

Only radio stations that are licensed for public correspondence accept messages from the general public for transmission by radio. Most radio stations in the various services such as police, fire, forestry, aeronautical, highway maintenance, highway trucking, industrial, intercity bus, railroad, and taxicab carry on nonpublic communications for their own service or business. Point-to-point and land mobile stations in the Public Radiocommunications Services, a number of coast stations, most ship stations, and some aircraft stations are open to public correspondence and make charges for the transmission of messages from the public in accordance with tariff regulations.

After listening for long periods to cw signals of constant tone, receiving operators may become fatigued. Often, operators avoid this fatigue by changing the pitch of the signal by slightly retuning the receiver or by readjusting the bfo control.

Many radiotelegraph systems employ break-in operation wherein the receiving station can break in on the transmitting station for the purpose of getting fill-ins or repeats of words missed. When break-in is employed, the transmitting operator is able to listen on the channel between dashes and dots, or at any time that his key is open.

In addition to the tuning control, most radiotelegraph receivers are equipped with a beat-oscillator control, selectivity control, rf gain con-

trol, audio gain control, antenna trimmer capacitor, and a crystal phasing control. Generally, when radiotelegraph signals are being received, the avc is off and the sensitivity is adjusted with the rf gain control. Normally, the rf gain control is adjusted to a point just below that at which the signals overload the receiver. The audio volume control is adjusted to the comfort of the receiving operator. In some receivers, the rf and af controls are combined into one control.

When interference and static are severe, the receiver is adjusted for sharp selectivity. The receiver is in sharpest selectivity when the crystal phasing switch is on.

Quite often, a radio station can be heard on a radio receiver at frequencies other than the assigned frequency of the transmitting station. Sometimes the fault is due to improper operation of the transmitting station, but in many instances it is due to the inherent characteristics of the receiver. If the cause is within the receiver, the operator can do little about it except to be aware of the phenomenon and perhaps by proper tuning of the receiver to avoid the effects. He will find that the desired station can be best received if he tunes in on the assigned frequency of the station rather than tuning in on an apparent frequency or image frequency on the receiver. The effect of receiving a signal on an "image" frequency may cause apparent interference to the desired signal, and the operator should be aware of this condition in order that he may make necessary adjustments.

QUESTIONS AND ANSWERS

1. List three classes of stations which may not be operated by the holder of a radiotelegraph third-class operator permit.—Television and broadcast stations, class I-B, II-B, and III-B coast stations, ship and coast stations open to public correspondence by telegraphy, and others. (RR 13.61)

2. Is the holder of a radiotelegraph third-class operator permit authorized to make technical adjustments to a radiotelephone transmitter? To a radiotelegraph transmitter?—No. He may not do so unless he is under the *direct supervision* of a person holding a first- or second-class commercial radio operator license, either radiotelephone or radiotelegraph as appropriate for the class of station involved. (RR 13.61)

3. Where should the operator on duty at a manually operated radiotelegraph station normally post his operator's license or permit?—The original license of each station operator shall be posted at the place where he is on duty, except as otherwise provided in Part 13 or in the rules governing the class of station concerned. (RR 13.6)

4. What are the requirements for station identification at radiotelegraph stations in the public safety radio services?—The station shall transmit an identification at the end of each transmission or exchange of transmissions, or once each 30 minutes of the operating period as the licensee may prefer. (RR 89.153)

5. What is the radiotelegraph distress signal? Urgency signal? Safety signal?—The distress signal consists of three dots, three dashes, and three dots, transmitted continuously: SOS. The urgency signal is X X X. The safety signal is T T T. When either message is transmitted, it is followed by DE and the call signal of

the station transmitted three times. (ART 37-6, 37-35, and 37-40)

6. The speed of radiotelegraph code transmission, in cases of distress, urgency or safety, must not in general exceed what speed?—Sixteen words per minute. (ART 37-3)

7. What radiotelegraph signal is generally used in a call to all stations?—The call is CQ. (ART 31)

8. What is meant by the following radiotelegraph operating signals: R, AS, IMI, C, BT, K, AR, VA, DE?—

R—Received.
AS—Waiting.
IMI—This is the question mark.
C—Yes.
BT—This is the double hyphen.
K—Invitation to transmit.
AR—End of transmission.
VA—End of work (sent as a continuous signal).
DE—From.

9. If a radiotelegraph operator makes an error in transmitting message text, how does he indicate that an error has been made?—The error signal is a series of approximately 8 or 9 dots.

10. In testing a radiotelegraph transmitter, what signals are generally transmitted?—A series of V's.

11. In order to avoid confusion in transmitting numbers involving fractions, how should such numbers be transmitted? Give an example of such a number showing how it should be transmitted. – Refer to Appendix V. The fraction bar is — · · — ·, and a hyphen or dash — · · · · — is always transmitted between a whole number and a fraction. A typical example is:

1 2/5
one — · · · · — two — · · — · five

12. What is meant by the preamble in a radiotelegraph message? What information is usually given in the preamble?—The preamble is sent ahead of the address or chargeable part of the message. The preamble includes the type of message, number of words, message number, and station to which the message is being sent. Also included are the time that the message was sent and filed as well as the station of origin and rate. (Summary)

13. In addition to the preamble, what parts does a radiotelegraph message contain?—It contains the address, text, and signature.

14. What is meant by a service prefix or indicator in a radiotelegraph message?—A service indicator is a coded designation that appears as a group of letters in the preamble. Handling directions and other data can be abbreviated using this method.

15. What does word count or check mean in a radiotelegraph message?—Usually it indicates the number of words that will be charged. Sometimes it indicates the number of paid words as well as the number of actual words.

16. At what time, or times, does the serial numbering of radio messages begin? Does the period of numbering vary in some services?—Usually, serial numbers begin at 0000 GMT daily. There are exceptions among some foreign stations.

17. Code or cipher groups are often used in radiotelegraph messages for what purpose?—They are used for security reasons.

18. Immediately following the transmission of a radiotelegraph message containing figures or odd symbols, why are such figures sometimes collated?—They are collated to make certain of their accuracy.

19. If receiving conditions are bad and you desire that the transmitting station send each word or group twice to facilitate reception, what operating signal would be appropriate to use?—The Q signal for sending each word or group twice is QSZ.

20. In general, what is the purpose of a service message in radiotelegraph communications?—A service message refers to a message handled previously. It usually involves a correction.

21. Why are Q signals or other arbitrarily selected procedure signals used in radiotelegraph communications? — They permit a short transmission time in the handling of common phrases. They are used internationally and overcome language problems.

22. What is meant by the following signals: QRA, QRM, QRN, QRT, QRZ, QSA, QSV, QUM, QRL?—Refrer to Appendix III. Note that when a Q signal is sent followed by a question mark you are asking a question. Otherwise, you are giving an answer or advice.

23. If the signal strength of a radiotelegraph signal is reported on a scale of 1, 2, 3, 4, 5, what scale number indicates a very strong signal? What scale number would indicate a very weak signal?—The highest number (5) represents a very strong signal, while the lowest number (1) represents a very weak signal.

24. If, upon being called by another station, a called station is busy with other traffic, what should the operator of the called station do?—He should acknowledge the call and conclude by indicating a number signifying the number of minutes of delay. If the delay will be greater than 10 minutes, he should also indicate the reason for such delay.

25. Describe a procedure of radiotelegraph transmission in which one station calls another. Give an example.—The call is made in the sequence: call sign of station called (repeated no more than three times), the word DE, followed by the sign of the station calling (repeated no more than three times).

WCDY WCDY WCDY DE
KCHO KCHO KCHO K

26. Describe a procedure of radiotelegraph transmission in which one station answers the call of another. Give an example.—The reply is made in a manner similar to the call, followed by the letter R, indicating that the call has been received.

KCHO KCHO KCHO DE
WCDY WCDY WCDY R K

27. What is meant by the statement that a station is open to public correspondence?—Such a station handles paid or toll radio messages for the general public at established rates. (Summary)

28. Should the speed of transmission of radiotelegraph signals be in accordance with the desire of the transmitting or receiving operator?—It is the decision of the receiving operator, because he must be able to copy the message.

29. What adjustment can the operator make to a radio receiver to relieve hearing fatigue caused by a long period of listening to a cw telegraph signal of constant tone?—He can change the frequency of the tone with the bfo control.

30. What is meant by break-in operation at a radiotelegraph station?—In a station with break-in facility, there is automatic switching between the receive and transmit modes. When the key is up, the station is capable of receiving a signal. Two stations with break-in capabilities are able to interrupt each other, informing the sending station immediately when the receiving station has missed a part of the message or is being troubled with static or interference.

31. How should the automatic-volume-control switch be set for reception of cw radiotelegraph signals on a communications receiver designed for both radiotelephone and radiotelegraph reception?—In many receiver designs, the avc switch should be set to its off position. (Some modern receivers include a fast avc, and this mode of reception can sometimes be used to advantage in the reception of radiotelegraph signals.)

32. Explain the use of the crystal filter switch on a communications receiver.—In communications receivers, the insertion of the crystal filter narrows the receiving bandwidth. It can be switched in when there are interference problems. As a result, the desired signal must then be tuned in very carefully, and in so doing, interference from stations operating on nearby frequencies can be minimized. Such a filter is also helpful in reducing the influence of static and other types of interference because it narrows the receiver bandwidth.

33. What adjustment should be made to a radiotelegraph receiver if the receiver blocks on the reception of strong signals?—Reduce the setting of the radio-frequency gain control.

35. How should a radiotelegraph receiver be adjusted for the reception of type A2 emissions?—Turn off the bfo and then adjust the receiver for the reception of a tone-modulated signal.

36. Sometimes a given radiotelegraph transmitting station can be heard at more than one place on the tuning dial of the receiver. Is this always an indication that the station is transmitting on more than one frequency?—The station is not transmitting on more than one frequency. It is an indication that the receiver is being tuned to an image frequency. The image-frequency signal will be weaker than the signal level received when the receiver is set to the proper frequency of the transmitting station.

37. How should a manual radiotelegraph transmitting key be adjusted for good operation? Is the adjustment always the same for slow as it is for high speed?—The contact opening of the key is usually adjusted for about 1/16 inch. Spring tension usually depends upon the individual's comfort requirements, although higher tension is advisable for the higher code speeds. Also, contact spacing can be less for high-speed operation. Side adjustments also permit properly aligned but free vertical movement of the arm.

38. Describe how an automatic key or bug should be properly adjusted to send good readable radiotelegraph signals.—With a bug, the dashes are made manually, and one need only adjust the dash arm for proper alignment and the required spacing (between 1/32 and 1/16 inch) and proper spring tension. The dot speed is set by the weights on the arm of the bug; a dot-contact spacing of about 1/8 inch is used. Usually the tension is such that 15 or more clear dots are sent continuously when the dot lever is held on the keying position. However, the adjustment weights must be set so that the dot speed corresponds to the desired code transmission speed that is to be sent.

CHAPTER 5

DC and AC Electricity, Element 6

The next ten chapters cover element 6. The subject matter is advanced radiotelegraphy, largely technical questions about equipment and circuits. Rules and other matters are also a part of this element. For study convenience, the subject matter has been arranged as follows:

Chapter	*Topic*
5	DC and AC Electricity
6	Electron Tubes and Amplification
7	Basic Amplifiers and Classes
8	Basic Oscillators
9	Power Sources
10	Radiotelegraph Transmitters and Antennas
11	Modulation and Test Equipment
12	Radio Receivers
13	Direction Finding and Alarm Systems
14	Rules and Regulations

Element 6 consists of 100 questions.

DEFINITIONS AND UNITS

1. By what other expression may a difference of potential or electromotive force be described?—It may be described as voltage or voltage drop. The unit of electromotive force (emf) is the volt.

2. By what other expression may an electric current flow be described?—It is a motion of electrons. The unit of electric current flow is the ampere.

3. With respect to electrons, what is the difference between conductors and nonconductors?—In a conductor, the electron or electrons of the outer shell (valence electrons) of the atomic structure can, under the proper stress, be made to move freely from atom to atom. The outer electrons of a nonconductor are bonded more closely to each other; electrons are not exchanged freely with neighboring atoms, and there is no (or a minimum) current. The electrons are identical regardless of the material; it is their number and their positioning in the valence orbit that determines whether a material is a nonconductor or a conductor.

4. What is an electron? An ion?—An atom consists of a nucleus (composed of protons and neutrons) and one or more encircling negative electric charges. These are called electrons and are a tiny charge subdivision of atomic matter.

An ion is a charged atom or charged group of atoms. When an electron has been removed from the basic atomic structure, what remains is then called a positive ion; if an electron has been added to the structure, what results is called a negative ion.

5. Name four methods by which an electrical potential may be generated.—A number of ways are (1) motion of a conductor through a magnetic field, (2) motion of a magnetic field relative to a fixed conductor, (3) chemical activity as in the case of a battery, (4) thermal activity as in the case of the heating of a thermocouple, (5) photoelectric effect as in the case of a light cell, (6) piezoelectric effect as in the case of a frequency crystal, and (7) friction or voltage stress between two oppositely charged bodies.

6. What is the meaning of the prefix kilo?—Kilo is a prefix corresponding to 10^3, or one thousand. A kilohertz is 1000 hertz.

7. What is the meaning of the prefix meg?—Meg (sometimes mega) is a prefix corresponding to 10^6, or 1 million. A megahertz is 1,000,000 hertz.

8. What is the meaning of the prefix micro? Micromicro?—Micro is a prefix representing 10^{-6}, or 1/1,000,000. A microfarad is one millionth of a farad. Micromicro is a prefix corresponding to 10^{-12}, or 1/1,000,000,000,000. A modern term for micromicrofarad is picofarad. A micromicrofarad or a picofarad equals one million millionth of a farad.

9. Name four conducting materials in the order of their conductivity.—The order of conductivity of four materials used widely in electrical conductors is silver, copper, gold, and aluminum. This tells us that a silver conductor as compared to a copper conductor of the same dimensions has a higher conductivity and a lower resistance to the motion of electrical charges (current).

10. Name four materials which are good insulators at radio frequencies. Name four materials which are not good insulators at radio frequencies but which are satisfactory for use at commerical power frequencies.—Some good radiofrequency insulators are steatite, polyethylene, Pyrexglass, mica, and various plastics. Some insulators at power frequencies are porcelain, rubber, glass, fibers, and Bakelite. Some of the latter are reasonable insulators at higher frequencies but not as free of loss as the types mentioned previously.

11. Explain the factors that influence the resistance of a conductor.—Two factors are cross-sectional area and length. Others are the type of material and its resistivity plus the temperature. The greater the length of a given material, the higher is its resistance. The smaller the cross-sectional area of a given material, the higher is its resistance. Because of their atomic makeup, some materials have a low resistance per length while others have a high resistance per length. Metals used as conductors have, in general, a resistance that increases with temperature.

12. What effect does the cross-sectional area of a conductor have on its resistance per unit length?—Resistance varies inversely with the cross-sectional area. If the cross-sectional area is doubled, the resistance is halved.

13. If the diameter of a conductor of given length is doubled, how will the resistance be affected?—When the diameter is doubled, the cross-sectional area is increased by a factor of 4. Consequently, the resistance becomes one quarter of the previous value. Cross-sectional area varies with the square of the diameter.

14. How can the direction of flow of dc electricity in a conductor be determined?—It can be determined with an ammeter that has its terminal polarization marked. The ammeter needle deflects correctly when the electron flow is minus to plus through the meter. An alternative means of determining electron flow is with the use of a magnetic compass and the left-hand electrical rule.

15. Does the resistance of a copper conductor vary with variations in temperature? If so, in what manner?—Resistance increases with temperature rise. Copper is said to have a positive temperature coefficient. Carbon has a negative temperature coefficient, and its resistance decreases with an increase in temperature.

16. What factors determine the heat generated in a conductor carrying an electric current?—The resistance and current values. The heat varies directly with the resistance and with the square of the current.

17. What is the unit of resistance?—The unit of resistance is the ohm. Resistance is the reciprocal of conductance, or:

$$R = \frac{1}{G}$$

Resistance is the opposition to charge motion (current). One ohm corresponds to the resistance of a device that restricts the current to 1 ampere when the voltage across the device is 1 volt.

18. Define the term conductance.—Conductance is a term that indicates the ability of a circuit to conduct current. It is the mathematical ratio of current to the voltage which produces it. It is the reciprocal of resistance, or 1/R.

19. What is the unit of conductance?—The unit of conductance is the mho.

20. Define the term coulomb.—The unit of electrical charge is the coulomb. More exactly, it is the electrical charge that passes a given point in one second under a steady current of one ampere.

21. What is the unit of electrical power?—The unit of electrical power is the watt. It is the amount of energy (joules) dissipated per second by a current of 1 ampere in a resistance of 1 ohm.

22. What unit is used in expressing the alternating-current impedance of a circuit?—The unit of ac impedance is also the ohm. Impedance is the opposition to charge motion (current), either dc or ac. In the case of a dc circuit, the impedance is entirely resistive, and the term resistance is used instead of impedance. In an ac circuit, the impedance consists of a resistive component and, if present, a reactive (inductive or capacitive) component as well.

23. What is meant by ampere turns?—It is a measure of the magnetomotive force (mmf). Mathematically, it is the product of the number of turns times the amperes of current.

24. Define the term inductance.—Inductance is the opposition by a circuit or component to a change in current. This property causes a voltage to be developed across an inductor (coil) by changing magnetic lines of force.

25. What is the unit of inductance?—The unit of inductance is the henry. One volt develops across an inductance of one henry when the current change is one ampere per second.

26. What is the meaning of power factor?—Power factor is the ratio of true (active) power to apparent power. In equation form:

$$\text{Power Factor} = \frac{\text{True Power}}{\text{Apparent Power}}$$

$$= \frac{I^2R}{VA} = \frac{R}{Z} = \cos\theta$$

27. Define power factor.—Refer to question 26.

28. What is the difference between electrical power and electrical energy?—Electrical energy is the latent or stored ability to do work electrically. It is potential energy. Electrical power represents this stored energy in action. This is kinetic energy. In other words, power is energy in motion. The unit of electrical power is the watt; the unit of electrical energy is the joule. One watt equals one joule per second. The practical unit of electrical energy is the watt-hour, which is equal to 3600 joules.

29. What is the ratio of the peak value of a sine wave to the average value?—The ratio of the peak value to the average value is 1.57 to 1. Conversely, the average value of a sine wave is 0.636 times the peak value.

30. What is the meaning of the term leading power factor?—This means that the phase relationship between current and voltage is such that the current sine wave leads the voltage wave. As shown in Fig. 5-1, the peak of the current

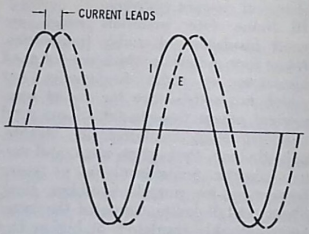


Fig. 5-1. Current leading voltage (leading power factor).

waveform comes ahead of the peak of the voltage waveform. Such a circuit is one with a capacitive reactance, and the voltage lags.

31. What is the meaning of the term phase difference?—Phase difference refers to the time displacement between two waves. As shown previously in Fig. 5-1, the current and voltage waveforms are displaced in time. In this example, the current sine wave has a leading phase compared to the voltage sine wave. One can also state that the voltage has a lagging phase relative to the current wave.

32. Indicate by a drawing a sine wave of voltage displaced 180° from a sine wave of current.—Refer to Fig. 5-2. Customarily, one states that these two waves are 180° out of phase.

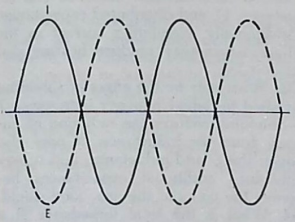


Fig. 5-2. Current and voltage with 180° phase relationship.

33. Define the following terms: Hysteresis, permeability, eddy current.—Hysteresis is a heat loss that occurs within magnetic material because of molecular friction. It occurs when a material is subject to a varying magnetic or electric field. Permeability determines how effectively a given material acts as a path for magnetic lines of force. In this comparison, the permeability of air is used as a reference with a value of unity. Eddy current is an undesired circulating current induced in a conductor by a varying magnetic field. This results in heat and loss of energy. Laminated structures are used to minimize eddy-current loss in transformers, chokes, armatures, etc.

34. Define the term permeability.—Refer to question 33.

35. What is the meaning of residual magnetism?—The level of magnetism present when the magnetizing force is zero. Residual magnetism is also indicated as the magnetic force remaining after the magnetizing source has been deactivated.

36. Which factors influence the direction of magnetic lines of force generated by an electromagnet?—These are the direction of charge motion (current) and the winding direction of the coil turns.

37. List at least two essentials for making a good soldered connection.—The essentials are a clean, firm joint, proper level of heat applied to the joint (not the solder), and appropriate solder formulation and flux for the metal types to be joined.

38. What are the ratios of peak to average values and peak to effective values of a sine wave?—The ratio of peak to average values is 1.57 to 1. The ratio of peak to effective values is 1.414 to 1. This may be stated:

$$I_{av} = 0.636 I_{peak}$$

$$I_{rms} = 0.707 I_{peak}$$

39. Define the term reluctance.—Reluctance is the opposition that a magnetic path offers to the flow of magnetic lines of force. Reluctance is also sometimes explained as magnetic resistance.

40. How many watts equal one horsepower?—746 watts. This early-day concept used as its standard the fact that one horsepower corresponds to the power needed to lift 550 pounds at the rate of one foot per second.

41. What single instrument may be used to measure electrical resistance? Electrical power? Electrical Current? Electromotive force?—The single instruments for each quantity are the ohmmeter, wattmeter, ammeter, and voltmeter, respectively.

CAPACITORS AND COILS

42. What is the unit of capacitance?—The unit of capacitance is the farad. A capacitance of one farad produces a cur-

rent of 1 ampere under the influence of a voltage change of 1 volt per second.

43. What factors determine the charge stored in a capacitor (condenser)?—The charge is determined by the capacitance and the applied voltage. In equation form:

$$Q(\text{coulombs}) = C(\text{capacitance in farads}) \times E(\text{volts})$$

44. What effect does a change in the dielectric constant of a capacitor dielectric material have on the capacitance of a capacitor?—Capacitance varies directly with dielectric constant. This constant corresponds to the ratio of capacitance with a given dielectric material to the capacitance that would exist if air were the dielectric.

45. If the specific inductive capacity of a capacitive dielectric material between the capacitor plates were changed from one to two, what would be the resultant change in capacitance?—Specific inductive capacity is a somewhat outmoded term for dielectric constant. If the dielectric constant is doubled, the capacitance would be twice the previous value.

46. Explain the effect of increasing the number of plates on the capacitance of a capacitor.—Increasing the number of plates increases the capacitance.

47. What factors determine the breakdown-voltage rating of a capacitor?—Breakdown voltage is determined by the quality of the dielectric material and its thickness (spacing between plates).

48. What is the effect of adding an iron core to an air-core inductance?—The inductance increases. The iron core presents a lower-reluctance path for the magnetic flux as compared to air.

49. What is the relationship between the number of turns and the inductance of a coil?—The inductance increases approximately as the square of the number of turns.

50. If temperature coefficients of resistance are neglected and the same gauge wire and the same applied voltage are used in each case, what would be the effect on the field strength of a single-layer solenoid of a small increase in the number of turns?—The field strength increases directly with the number of turns and the value of the current. If turns are added and the current is not decreased in the same proportion, the field intensity increases. However, if the current is decreased significantly with the increase in turns (high-resistance turns), there would be a decrease in field intensity.

51. What is the purpose of a choke coil?—Choke coils are designed to present opposition or a high impedance to ac current. At the same time, the choke has a low resistance to dc current. Some chokes are designed to offer a high impedance to certain high frequencies while they pass lower ac frequencies with little loss.

52. What will be the effect of a shorted turn in an inductance?—The net inductance of the coil will be decreased. The shorted turn can also influence coil resistance, Q, and distributed capacitance. Additionally, circulating current in the shorted turn may produce heating and circuit loss.

53. What may be the effect of shielding applied to radio-frequency inductances?—Shielding reduces the radiation of energy from the inductance. It may also lower the Q and inductance, and it may introduce additional capacitances between the coil and the grounded shield.

54. What is the total impedance if a capacitor and inductor have equal values of reactance when connected in parallel.—In such a parallel combination, the impedance rises to a maximum. If there were no resistance in the circuit, that maximum value would be infinity.

55. What changes in circuit constants will double the resonant frequency of a resonant circuit?—This can be accomplished by reducing the LC product to one-fourth its previous value. Such may be accomplished by decreasing either C or L to one-fourth of the previous value, or by halving both. Frequency varies inversely with the square root of the LC product:

$$f_o \propto \frac{1}{\sqrt{LC}}$$

56. How may the Q of a parallel resonant circuit be increased?—The Q is in-

creased by raising the inductive reactance or lowering the effective resistance ($Q = X/R_{eff}$). In a practical sense, it can be accomplished by choosing a proper L-to-C ratio, using low-loss capacitors and coils, and proper isolation to minimize stray losses.

57. What is meant by the time constant of certain electrical circuits containing resistance and capacitance?—Time constant represents the time needed for the voltage on a capacitor to build up to 63.2% of the applied value. It also represents the time needed for the current in an inductor to build up to 63.2% of its final value. The two time-constant equations are:

$$T = RC$$

$$T = \frac{L}{R}$$

58. What emergency repairs may be made to an inductance coil that has burned or charred insulation?—Minor damage can be handled by coating with a low-loss insulating material. Serious damage to a coil is best handled by installing a new winding.

59. What are some uses of a low-pass filter network?—There are many applications for filters, such as controlling amplifier bandwidth, power-supply filters, interstage coupling and decoupling networks, tone control, audio crossover networks, power-line filters, harmonic suppression filters, etc.

GENERAL

60. Which factors determine the amplitude of the emf induced in a conductor which is cutting magnetic lines of force?—These factors are the number of lines being cut, the strength of the magnetic field, the speed with which the conductor cuts the lines, and the angle of the conductor relative to the magnetic lines of force.

61. How may a magnetic compass be affected when placed within a coil carrying an electric current?—In this situation, the influence of the coil and its current will be greater than the attraction of the earth's magnetic field. The needle of the compass will orient itself along the axis of the coil; the arrow will point to the north pole of the coil.

62. Define the term decibel.—The decibel is the unit of change in sound or signal levels. A common expression for decibels in terms of power levels is:

$$\text{Decibels (dB)} = 10 \log \frac{P_2}{P_1}$$

where,

P_2 isthe output power,
P_1 is the input power.

63. What is meant by the efficiency of a radio device?—It is the ratio of useful power output to power input. This is the decimal quantity P_o/P_{in}. Efficiency in percentage is obtained by multiplying this ratio times 100.

64. Name at least five pieces of radio equipment which make use of electromagnets.—These include relays, phonograph recording heads, tape recording heads, loudspeakers, generators, and motors.

65. Why are permanent magnets used in head phones? In dc meters?—In a headset, the permanent magnet keeps a moving diaphragm under tension. Applied ac signals then cause the diaphragm to vibrate according to the audio variations. In a dc meter, a permanent magnet provides a constant magnetic field which is a reference level. The current to be measured can then be determined accurately because the meter movement will change away from reference in proportion to the magnitude of the current to be measured.

66. Why may a transformer not be used with direct current?—To transfer electrical power between the primary and secondary sides of a transformer, it is necessary that a changing current be present. This produces the changing magnetic lines of force that act as a path between primary and secondary. Changing current and magnetic flux cannot be obtained by applying a steady direct current.

67. Why is rosin used as a soldering flux in radio construction work?—It provides an excellent soldering bond which joins the two conductors into a low-resistance connection. It is also a noncorrosive material.

68. What is the relationship between the turns ratio and the impedance ratio of the windings of a transformer?—The impedance ratio of a transformer varies as the square of the turns ratio.

$$\frac{Z_s}{Z_p} = \left(\frac{N_s}{N_p}\right)^2$$

If the secondary has more turns than the primary, the transformer is said to have a step-up impedance ratio. Conversely, with fewer secondary turns than primary turns, there is a step-down impedance ratio.

69. What is the velocity of propagation of radio-frequency waves in space?—The velocity of a radio-frequency wave in space is 300,000,000 meters per second (approximately 186,000 miles per second). This is the same as the velocity of light.

70. What is the relationship between the effective value of a radio-frequency current and the heating value of the current?—The heating influence is related directly to the effective value of the radio-frequency current. In fact, this relationship is used to advantage in the design of the hot-wire radio-frequency thermocouple ammeter. Furthermore, a dc current and an ac rms current of the same value have the same heating effect.

71. What is meant by a harmonic?—A harmonic is a whole multiple of the fundamental frequency. The second harmonic of a 5-MHz frequency is 10 MHz. The fifth harmonic of the same frequency would be 25 MHz.

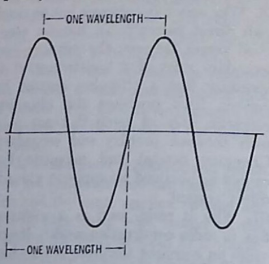


Fig. 5-3. Two cycles of a sine wave showing one wavelength.

72. Indicate by a drawing two cycles of a radio-frequency wave, and indicate one wavelength thereof.—Refer to Fig. 5-3. One wavelength corresponds to the distance between the start of one wave and the start of the next wave. However, it is to be noted that there is a wavelength separation between any two like positions on two adjacent waves. For example, one wavelength separates the positive peaks of two adjacent sine waves.

73. What is the second harmonic of 380 kilohertz?—The second harmonic of 380 kilohertz is 760 kilohertz (380×2).

PROBLEMS

74. State the three ordinary mathematical forms of Ohm's law.—

$$I = \frac{E}{R} \qquad R = \frac{E}{I} \qquad E = IR$$

E is measured in volts, I in amperes, and R in ohms.

75. What is the conductance of a circuit if the current is 6 amperes when 12 volts dc is applied to the circuit?—Conductance is the reciprocal of resistance and is measured in mhos.

$$G = \frac{1}{R}$$

$$G = \frac{1}{E/I} = \frac{I}{E}$$

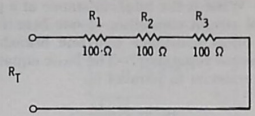
Substitution in the equation shows the conductance to be:

$$G = \frac{6}{12} = 0.5 \text{ mho}$$

76. Draw a simple schematic diagram showing the method of connecting three resistors of equal value so that the total resistance will be three times the resistance of one unit.—Refer to Fig. 5-4. When resistors are connected in series, the total resistance is the sum of their ohmic values. In our example this would be 300 ohms:

$$R_T = R_1 + R_2 + R_3$$
$$= 100 + 100 + 100 = 300 \text{ ohms}$$

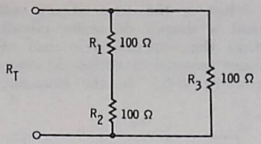
This is three times the value of a single resistor.



$R_T = R_1 + R_2 + R_3$

$R_T = 3R_1 = 3R_2 = 3R_3$

Fig. 5-4. Three equal resistors connected in series to triple the resistance.



$R_T = \frac{2}{3}R_1 = \frac{2}{3}R_2 = \frac{2}{3}R_3$

Fig. 5-6. Series-parallel circuit for 2/3 times value of one of three equal resistors.

77. Draw a simple schematic diagram showing the method of connecting three resistors of equal value so that the total resistance will be one third of the resistance of one unit.—Refer to Fig. 5-5. The ohmic value of three resistances in parallel can be determined as follows:

$$R_T = \frac{1}{\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}}$$

In Fig. 5-5, each resistor has a value of 100 ohms:

$$R_T = \frac{1}{\frac{1}{100} + \frac{1}{100} + \frac{1}{100}}$$

$$= \frac{100}{3} = 33\frac{1}{3} \text{ ohms}$$

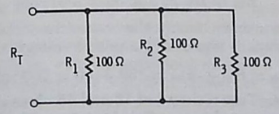
This is one-third of the 100-ohm value of each resistor.

78. Draw a simple schematic diagram showing the method of connecting three resistors of equal value so that the total resistance will be ⅔ of the resistance of one unit.—Refer to Fig. 5-6. In this arrangement, two series resistors are placed in parallel with the third resistor. The two resistors in series have a value of 200 ohms in our example. This effective 200 ohms is then placed in parallel with resistor R3 of 100 ohms. The net resistance becomes:

$$R_T = \frac{(R_1 + R_2) \times R_3}{(R_1 + R_2) + R_3}$$

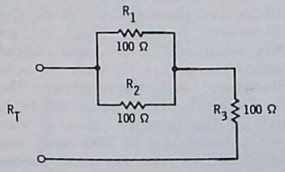
$$= \frac{200 \times 100}{200 + 100} = 66\frac{2}{3} \text{ ohms}$$

79. Draw a simple schematic diagram showing the method of connecting three resistors of equal value so that the total resistance will be 1½ times the resistance of one.—Refer to Fig. 5-7. Assume each resistor has a value of 100 ohms. Resistors R_1 and R_2 are in parallel, and their net resistance is 50 ohms. Adding this value to the value of resistor R_3 produces a total resistance value of 150 ohms.



$R_T = \frac{R_1}{3} = \frac{R_2}{3} = \frac{R_3}{3}$

Fig. 5-5. Three equal resistors connected in parallel to give one third of the resistance.



$R_T = 1\ 1/2R_1 = 1\ 1/2R_2 = 1\ 1/2R_3$

Fig. 5-7. Series-parallel circuit for 1½ times value of one of three equal resistors.

80. What is the sum of all voltages around a simple dc series circuit, including the source?—The sum of the voltages around a series dc circuit is zero (Fig. 5-8). In the example, the

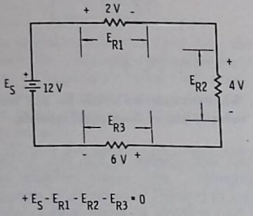


Fig. 5-8. Sum of voltages around a closed circuit is zero.

source voltage is 12 volts. The voltage drops across the three resistors are 2, 4, and 6 volts, respectively. If you now add the voltages algebraically and include the source voltage, the net voltage will be zero.

$$E_S - E_{R1} - E_{R2} - E_{R3} = 0$$
$$12 - 2 - 4 - 6 = 0$$

Often this rule is stated in a manner which says the sum of the voltage drops equals the source voltage, or:

$$E_S - E_{R1} - E_{R2} - E_{R3} = 0$$
$$E_S = E_{R1} + E_{R2} + E_{R3}$$
$$12 = 2 + 4 + 6$$

81. If the voltage applied to a circuit is doubled and the resistance of the circuit is increased to three times its former value, what will be the final current?—Current varies directly with the voltage and inversely with the resistance. Therefore, the final current value will be two-thirds of the original value. If we assume a resistance of 100 ohms and a voltage of 100 volts, the result becomes:

$$I_1 = \frac{100}{100} = 1 \text{ ampere}$$

$$I_2 = \frac{2 \times 100}{3 \times 100} = \frac{200}{300} = \frac{2}{3} \text{ ampere}$$

82. What is the total resistance of a parallel circuit consisting of one branch of 10 ohms resistance and one branch of 25 ohms resistance?—The basic equation for resistors in parallel is:

$$R_T = \frac{1}{\frac{1}{R_1} + \frac{1}{R_2}}$$

This can be simplified to a simple product-over-sum relationship when only two resistors are to be considered. Therefore, the total resistance becomes:

$$R_T = \frac{R_1 R_2}{R_1 + R_2} = \frac{10 \times 25}{10 + 25} = 7.14 \text{ ohms}$$

83. Two resistors are connected in series. The current to these resistors is 3 amperes. One resistor has a value of 50 ohms; the second resistor has a voltage drop of 50 volts across its terminals. What is the total impressed emf?—The simple circuit is shown in Fig. 5-9. The

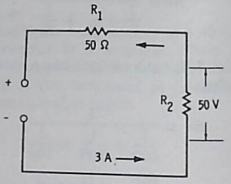


Fig. 5-9. Circuit for question 83.

voltage drop across resistor R2 is already known to be 50 volts. In the case of resistor R1, the ohmic value and current are known. Therefore Ohm's law can be used to determine the voltage drop across R1:

$$E_{R1} = IR_1 = 3 \times 50 = 150 \text{ volts}$$

In a series circuit, the sum of the voltage drops is equal to the source voltage, or:

$$E_T = E_{R1} + E_{R2} = 150 + 50 = 200 \text{ volts}$$

84. Two resistors of 18 and 15 ohms are connected in parallel; in series with this combination is connected a 36-ohm resistor; in parallel with this total combination is connected a 22-ohm resistor. The total current through the combination is 5 amperes. What is the current

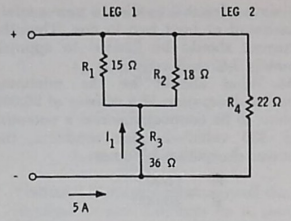


Fig. 5-10. Circuit for question 84.

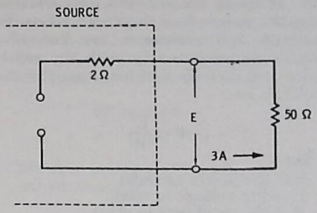


Fig. 5-11. Circuit for question 85.

value in the 15-ohm resistor?—The circuit is shown in Fig. 5-10. A sequence of steps must be followed in finding the answer. However, keep in mind that the problem asks for the current value in only the 15-ohm resistor. The resistance of leg 1 is:

$$R_T = \frac{15 \times 18}{15 + 18} + 36 = 44 \text{ ohms}$$

This is twice the resistance of leg 2. The current divides in inverse proportion to the resistances of the two legs. Therefore, the current in leg 1 is:

$$I_1 = \frac{22}{22 + 44} \times 5 = \frac{1}{3} \times 5 = 1\frac{2}{3} \text{ A}$$

However, the current in R_1 is only

$$I_{R1} = \frac{R_2}{R_1 + R_2} \times 1\frac{2}{3}$$
$$= \frac{18}{15 + 18} \times 1\frac{2}{3} = 0.9 \text{ A}$$

85. A circuit is passing a current of 3 amperes. The internal resistance of the source is 2 ohms. The total external resistance is 50 ohms. What is the terminal voltage of the source?—In this question, the internal resistance of the source is mentioned. It acts effectively in series with the external resistance as shown in the diagram of Fig. 5-11. However, the current is known and is of the same value in the series source resistance and external resistance. It is therefore possible to determine the terminal voltage using Ohm's law:

$$E = IR = 3 \times 50 = 150 \text{ volts}$$

86. A certain keying-relay coil has a resistance of 500 ohms and is designed to operate on 125 mA. If the relay is to operate from a 110-volt dc source, what value of resistance should be connected in series with the relay coil?—This circuit is shown schematically in Fig. 5-12. The required voltage drop across the relay coil is:

$$E_{RY} = IR = 500 \times 0.125 = 62.5 \text{ volts}$$

The voltage source is 110 volts, and therefore the voltage drop across the external resistor must be 47.5 volts (110 — 62.5). Ohm's law can then be used to determine the ohmic value of the resistor:

$$R_S = \frac{E}{I} = \frac{47.5}{0.125} = 380 \text{ ohms}$$

87. What is the formula for determining the power in a dc circuit when the current and voltage are known?—Power varies directly with the voltage and current, or:

$$P = EI$$

where,

P is the power in watts,
E is the voltage in volts,
I is the current in amperes.

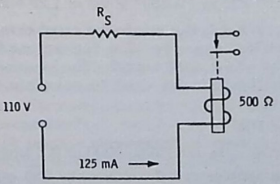


Fig. 5-12. Circuit for question 86.

88. What is the formula for determining the power in a dc circuit when the voltage and resistance are known?—Power varies inversely with the resistance and directly with the square of the voltage, or:

$$P = \frac{E^2}{R}$$

where,

P is the power in watts,
E is the voltage in volts,
R is the resistance in ohms.

89. What is the formula for determining the power in a dc circuit when the current and resistance are known?—Power varies directly with the resistance and the square of the current, or:

$$P = I^2R$$

where,

P is the power in watts,
I is the current in amperes,
R is the resistance in ohms.

90. If the value of a resistance across which a constant emf is applied is doubled, what will be the resultant proportional power dissipation?—The power will be halved. Assuming a constant voltage, the power varies inversely with the resistance.

91. If the value of a resistance to which a constant emf is applied is halved, what will be the resultant proportional power dissipation?—The power dissipation will double. Again, power varies inversely with the resistance, assuming a constant applied emf.

92. What will be the heat dissipation in watts of a resistor of 20 ohms having a current of one-quarter ampere passing through it?—Again the power equation is used:

$$P = I^2R = (0.25)^2 \times 20 = 1.25 \text{ watts}$$

93. What is the maximum rated current-carrying capacity of a resistor marked 5000 ohms, 200 watts?—The power-law equation can be used to calculate this current:

$$P = I^2R$$

$$I = \sqrt{P/R} = \sqrt{200/5000} = 0.2 \text{ ampere}$$

The answer is 0.2 ampere, or 200 milliamperes. (In a practical situation, it is always advisable to allow a power safety factor of at least two to one. Thus the current should be limited to approximately 140 milliamperes.)

94. What should be the minimum power dissipation of a resistor of 20,000 ohms to be connected across a potential of 500 volts?—In this condition, the power dissipation becomes:

$$P = \frac{E^2}{R} = \frac{(500)^2}{20{,}000} = 12.5 \text{ watts}$$

In a practical case, a two-to-one safety ratio is advisable. Therefore, the power rating of the resistor should be at least 25 watts. It can be more, but it should not be less.

95. If two 10-watt, 500-ohm resistors are connected in series what is the total power-dissipation capability?—It is 20 watts, each resistor with a power dissipation capability of 10 watts.

96. If two 10-watt, 500-ohm resistors are connected in parallel, what is the total power-dissipation capability?—It is also 20 watts, each resistor being capable of dissipating 10 watts. The power-dissipation capability of a resistor does not change regardless of the type of circuit in which it is connected. Therefore, the total power-dissipation capability varies directly with the number of like resistors connected in series or parallel.

97. A 10,000-ohm, 100-watt resistor, a 40,000-ohm, 50-watt resistor, and a 5000-ohm, 10-watt resistor are connected in parallel. What is the maximum value of total current in this parallel combination which will not cause the wattage rating of any of the resistors to be exceeded?—First it is necessary to determine the safe voltage that can be applied across each of the resistors. Checking values indicates that the safe voltage is limited by the lowest ohmic value and the lowest power rating of the third resistor.

$$E = \sqrt{PR} = \sqrt{10 \times 5000} = 224 \text{ volts}$$

The lowest voltage must be used to prevent excessive power dissipation in the 5000-ohm resistor. Since the resistors are connected in parallel, this is the maximum voltage that can be applied to the parallel circuit. The current in each re-

sistor can then be determined as follows:

$$I_{R1} = \frac{224}{10{,}000} = 22.4 \text{ mA}$$

$$I_{R2} = \frac{224}{40{,}000} = 5.6 \text{ mA}$$

$$I_{R3} = \frac{224}{5000} = 44.8 \text{ mA}$$

The total current is the sum of the individual branch currents in a parallel circuit, or:

$$I_T = 22.4 + 5.6 + 44.8 = 72.8 \text{ mA}$$

(In a practical situation, it is advisable to employ a safety factor by limiting the applied voltage and resultant current to a somewhat lower value.)

98. State Ohm's law for ac circuits.

$$I = \frac{E}{Z} \qquad Z = \frac{E}{I} \qquad E = IZ$$

The Z term consists of both resistance and reactance. The latter term can be either inductive or capacitive as determined by the equation:

$$Z = \sqrt{R^2 + (X_L - X_C)^2}$$

If a circuit is entirely resistive (contains no reactance), the equation becomes:

$$Z = R$$

99. What is the impedance of a solenoid if its resistance is 5 ohms and 0.3 ampere flows through the winding when 110 volts at 60 hertz is applied to the solenoid?—The voltage and current are known, and the impedance can be determined as follows:

$$Z = \frac{E}{I} = \frac{110}{0.3} = 367 \text{ ohms}$$

100. If the power input to a radio receiver is 75 watts, how many kilowatt hours does the receiver consume in 24 hours of continuous operation?—The consumption rate is 75 watts (0.075 kw). Therefore:

$$\text{kWH} = P_{kw} \times H$$
$$= 0.075 \times 24 = 1.8 \text{ kWH}$$

101. If a 220-volt, 60-hertz, single-phase line delivers 100 watts at 80% power factor to a load, what is the phase angle between the line current and line voltage? What is the current in the line?—The power-factor equation can be used to determine the phase angle:

$$PF = \cos \theta$$
$$\theta = \cos^{-1} 0.8 = 37°$$

The true power is 100 watts, and the apparent power is:

$$P_{app} = \frac{P_T}{PF} = \frac{100}{0.8}$$
$$= 125 \text{ volt-amperes (VA)}$$

The above information permits you to calculate the current:

$$P_{app} = VA$$
$$A = \frac{P_{app}}{V} = \frac{125}{220} = 0.568 \text{ A}$$

102. What is the total inductance of two coils connected in series but without any mutual coupling?—The total inductance is the sum of the inductances of the two coils. Inductances in series add, or:

$$L_T = L_1 + L_2 + L_3 + \text{etc.}$$

103. What is the total inductance of two coils connected in parallel but without any mutual coupling?—In a parallel combination, the net inductance decreases in the manner shown by:

$$L_T = \frac{1}{\frac{1}{L_1} + \frac{1}{L_2} + \frac{1}{L_3} + \text{etc.}}$$

For the case of only two inductors, the equation reduces to:

$$L_T = \frac{L_1 L_2}{L_1 + L_2}$$

In the parallel combination, the total inductance will always be less than the inductance of either one of the two coils.

104. A series inductance acting alone in an alternating-current circuit has what properties?—A series inductor opposes the passage of alternating current. In so doing, it causes the circuit current to lag the applied voltage by 90°. The current has a value of:

$$I = \frac{E}{X_L} = \frac{E}{2\pi fL}$$

This tells us that the current varies directly with the voltage but inversely with frequency and inductance.

105. What turns ratio should a transformer have which is to be used to match a source impedance of 500 ohms to a load of 10 ohms?—Impedance varies as the square of the turns ratio.

$$\text{Impedance ratio} = (\text{Turns ratio})^2$$

$$\text{Turns ratio} = \sqrt{\text{Impedance ratio}}$$

$$\text{Turns ratio} = \sqrt{\frac{500}{10}} = \sqrt{50} = 7.1 \text{ to } 1$$

106. State the formula for determining the quantity of charge on a capacitor.—

$$Q = CE$$

where,
Q is the charge in coulombs,
C is the capacitance in farads,
E is the voltage in volts.

The joule is a measure of energy or work. The energy stored by the capacitor is a function of the average voltage and the charge:

$$W = \frac{1}{2}EQ = \frac{1}{2}CE^2$$

where,
W is the stored energy in joules,
Q is the charge in coulombs,
C is the capacitance in farads,
E is the voltage in volts.

107. The charge in a capacitor is stored in what portion of the capacitor?—In a capacitor, energy is stored in the form of an electrostatic field. Actually, the energy is in the form of electron charges that exert their stress between plates and across the dielectric material. An inductor stores its energy in the form of a magnetic field.

108. The voltage drop across an individual capacitor of a group of capacitors connected in series across a source of potential is proportional to what factors?—With an ac source, the factors are the relative capacitance values and the potential of the ac source. The individual capacitor voltage is related directly to the source voltage and the ratio of the reactance of the particular capacitor to the total reactance of the series combination. If the source is a dc voltage, the voltage division is in accordance with relative leakage resistances.

109. If capacitors of 1, 3, and 5 microfarads are connected in parallel, what is the total capacitance?—In a parallel combination, the total capacitance is the sum of the individual capacitances, or:

$$C_T = C_1 + C_2 + C_3 + \text{etc.}$$

$$C_T = 1 + 3 + 5 = 9\mu F$$

110. What is the formula used to determine the total capacitance of three or more capacitors connected in series?—It is the reciprocal of the sum of the reciprocals, or:

$$C_T = \frac{1}{\frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3} + \frac{1}{C_4} + \text{etc.}}$$

111. If capacitors of 5, 3, and 7 microfarads are connected in series, what is the total capacitance?—The reciprocal equation is used as follows:

$$C_T = \frac{1}{\frac{1}{3} + \frac{5}{1} + \frac{1}{7}}$$

$$= \frac{1}{\frac{35 + 21 + 15}{105}} = 1.48\ \mu F$$

112. What is the total reactance when two capacitances of equal value are connected in series?—The total reactance is the sum of the individual reactances, or:

$$X_T = X_1 + X_2$$

113. How many capacitors rated at 400 volts and 2 μF each would be necessary to obtain a combination rated at 1600 volts and 1.5 μF?—A network such as that shown in Fig. 5-13 would be set up. When 400-volt capacitors are used, a series of four of them is needed to obtain a rating of 1600 volts. However, four 2-μF capacitors in series results in a net capacitance of 0.5 μF. To obtain a total capacitance of 1.5 μF, it is necessary to connect three such capacitor groups in a parallel combination, or a total of 12 capacitors.

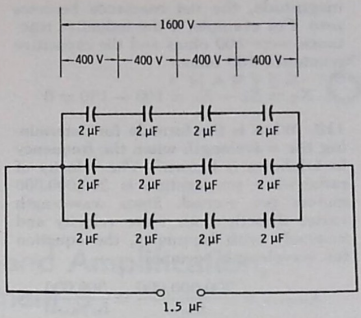


Fig. 5-13. Series-parallel capacitor grouping.

114. One of two identical mica capacitors of 0.1-μF capacitance is charged to a potential of 125 volts and disconnected from the charging source. The charged capacitor is then connected in parallel with the uncharged capacitor. What voltage appears across the two capacitors connected in parallel?—The answer is 62.5 volts. The charge on the charged capacitor is the product of voltage and capacitance, or:

$$Q = CE$$

If a capacitor of like value is now placed across the charged capacitor, the energy divides. The voltage must of necessity halve because there has been no change in the total energy.

115. What is the reactance of a 0.01-μF capacitor at a frequency of 3000 hertz? What is the reactance of a 2-henry choke coil at the same frequency?—The two basic equations for reactance are:

$$X_L = 2\pi fL \qquad X_C = \frac{1}{2\pi fC}$$

Inductive reactance is determined as follows:

$$X_L = 6.28 \times 3000 \times 2 = 37{,}680 \text{ ohms}$$

The capacitive reactance is determined as follows:

$$X_C = \frac{1}{6.28 \times 3000 \times 0.01 \times 10^{-6}}$$

$$= 5307 \text{ ohms}$$

116. What is the total impedance of a series ac circuit that has a resistance of 3 ohms, an inductive reactance of 7 ohms, and zero capacitive reactance.—The impedance equation is used as follows:

$$Z = \sqrt{R + (X_L - X_C)^2}$$

$$Z = \sqrt{(3)^2 + (7 - 0)^2} = 7.6 \text{ ohms}$$

117. What is the total impedance of a series ac circuit that has an inductive reactance of 14 ohms, a resistance of 6 ohms, and a capacitive reactance of 6 ohms?—

$$Z = \sqrt{R^2 + (X_L - X_C)^2}$$

$$Z = \sqrt{(6)^2 + (14 - 6)^2} = 10 \text{ ohms}$$

118. What is the total reactance of a series ac circuit containing no resistance and equal values of inductive and capacitive reactance?—Inductive and capacitive reactances are subtractive (X_C having a negative sign). Any voltage developed across the capacitive reactance would have a 180° phase relationship to the voltage across the inductive reactance of the series circuit. The reactances still add in the series circuit, but one must consider the negative sign of the capacitive reactance as follows:

$$X_T = X_L + (-X_C)$$

$$X_T = X_L - X_C$$

Since the two reactances have the same

magnitude, the net reactance becomes zero. For example, if the inductive reactance were 100 ohms and the capacitive reactance 100 ohms:

$$X_T = X_L - X_C = 100 - 100 = 0$$

119. What is the formula for determining the wavelength when the frequency in kilohertz is known?—The velocity of radio-wave propagation is 300,000,000 meters per second. Since wavelength varies directly with wave velocity and inversely with frequency, the equation for wavelength becomes:

$$\lambda_{meters} = \frac{300{,}000{,}000}{f_{hertz}} = \frac{300{,}000}{f_{kilohertz}}$$

120. If the period of one complete cycle of a radio wave is 0.000001 second, what is the frequency?—The frequency is the reciprocal of the period of a wave. Therefore:

$$f = \frac{1}{P} = \frac{1}{0.000001}$$

$$= 1{,}000{,}000 \text{ hertz} = 1 \text{ megahertz}$$

121. State the formula for determining the resonant frequency of a circuit when the inductance and capacitance are known.—The frequency varies inversely with the square root of the LC product. The equation is:

$$f = \frac{1}{2\pi\sqrt{LC}}$$

This equation applies for both series and parallel resonant circuits. However, it does result in some error in the parallel case if the Q is lower than a value of about 12.

122. If a parallel circuit, resonant at 1000 kilohertz, has the value of inductance halved and the value of capacitance doubled, what will be the resultant resonant frequency?—There will be no change in resonant frequency. The equation for resonance is:

$$f = \frac{1}{2\pi\sqrt{LC}}$$

This equation tells us that the frequency varies inversely with the square root of the LC product, or:

$$f \propto \frac{1}{\sqrt{LC}}$$

If the inductance is halved and the capacitance doubled, there will be no change in the LC product. Consequently, there will be no change in the resonant frequency.

123. What is the resonant frequency of a tuned circuit consisting of a capacitor of 500 pF, a coil of 150 μH, and a resistance of 10 ohms?—The resonant frequency is determined as follows:

$$f = \frac{1}{6.28\sqrt{150 \times 10^{-6} \times 500 \times 10^{-12}}}$$

$$= 0.581 \text{ MHz}$$

124. Assume an inductance of 5 henrys in parallel with a capacitance of 1 μF. If there is no resistance in either leg of this circuit, what is the equivalent impedance of the parallel network at resonance?—Since there is no resistance, the impedance at resonance is infinite.

CHAPTER 6

Electron Tubes and Amplification, Element 6

STRUCTURES AND CHARACTERISTICS

125. Describe the physical structure of a triode vacuum tube.—A triode is a three-element tube consisting of a heater-cathode, control grid, and plate, all mounted within an evacuated glass, metal, or ceramic case (Fig. 6-1). At the center of the structure is a cathode which acts as a source of electrons when heated. The cathode electron-emitting surface can be heated directly or indirectly. The cathode is surrounded by a control grid made of a fine wire mesh. Its grid-like construction is such that the electrons can readily pass through the wire and move on toward the more positive plate. The grid function is to control the number of electrons flowing from cathode to plate.

The plate is a solid electrode that surrounds the grid. A positive potential (with respect to the cathode) is applied to the plate, which then attracts the electrons emitted by the cathode.

When heated directly, the filament wire emits the electrons. A separate cathode surface can be heated indirectly. The heat from a filament wire raises the cathode surface to a temperature that causes the special coating on the cathode surface to emit electrons.

126. Describe the physical structure of a tetrode vacuum tube.—A tetrode is similar to a triode except for an additional electrode between the grid and plate (Fig. 6-2). This additional electrode, called a screen grid, makes the plate current much more independent of the plate voltage. In effect, it acts as a shield between the plate and the grid surface, minimizing feedback between the input and output circuits by way of the internal tube capacitance. The screen grid is also made of a fine wire mesh and permits the easy passage of electrons enroute to the plate. Because it operates at a positive potential, the screen grid has a substantial influence on the amount of plate current. The tetrode has four elements instead of three.

127. Describe the physical structure of the triode, tetrode, and pentode vacuum tubes on a comparative basis.—The pentode is a five-element tube. It is similar to the tetrode in construction except that it has an additional electrode (suppressor grid) between the screen grid and the plate (Fig. 6-3). The primary function of this electrode is to counteract secondary emission at the plate, producing a more linear range of operation than is possible with the tetrode.

In physical structure, the triode, tetrode, and pentode tubes have three, four, and five elements, respectively. All three have a cathode and a plate. The triode has a single mesh grid called a

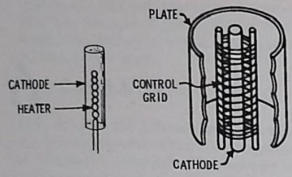


Fig. 6-1. Basic construction of a triode tube.

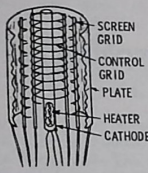


Fig. 6-2. Basic construction of a tetrode tube.

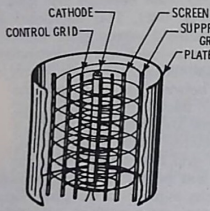


Fig. 6-3. Basic construction of a pentode tube.

control grid. The tetrode has two mesh grids, the control grid and screen grid. The pentode has three mesh grids, the control grid, screen grid, and suppressor grid.

128. Describe the electrical characteristics of the pentode, tetrode, and triode vacuum tubes on a comparative basis.— In a triode vacuum tube, the cathode is the source of electrons. These electrons are attracted to the plate. The control grid inserted between the cathode and the plate is able to regulate the electron flow. Inasmuch as a small voltage change at the control grid can cause a substantial variation in the plate current, such a device can be used as an amplifier. Both the plate and the control grid exert control over the plate current, with the control grid dominating that control. As compared to the other vacuum-tube types, the triode has a poor efficiency. However, it is noted for its low distortion characteristic.

In a tetrode, an additional grid is inserted between the control grid and the plate. A positive potential is applied to the screen grid, and it exerts a substantial control over the plate current. However, since it is of mesh construction, the electrons attracted by the screen grid pass readily on to the plate. The influence of the screen grid on the magnitude of the plate current is now greater than that of the plate. This means that plate-voltage change has less effect on plate current, and it is possible to obtain much higher gain than is feasible with a triode. The insertion of the screen grid also reduces effective tube capacitances and provides a higher degree of isolation between output and input circuits. Thus, in many high-frequency amplification services it is not necessary to neutralize a tetrode even though triodes must be neutralized in similar applications.

One of the disadvantages of the tetrode is that at low plate voltage some of the electrons leave the plate and move to the screen grid. This introduces distortion and limits the magnitude of the linear output-voltage change. A pentode vacuum tube has an additional mesh grid inserted between the screen grid and the plate. This suppressor grid is operated at or near cathode potential. Therefore, secondary electrons are blocked in their movement from plate to screen grid. Pentodes have even lower effective interelectrode capacitances and permit operation without neutralization at even higher radio frequencies.

The curves of Fig. 6-4 provide a summarizing comparison among the triode, tetrode, and pentode. Triodes are characterized by low plate resistance (R_p) and low to moderate values of amplification factor (μ). A triode is often referred to as a constant-voltage generator because its plate voltage is rather independent of plate current for any constant value of grid bias (refer to the tri-

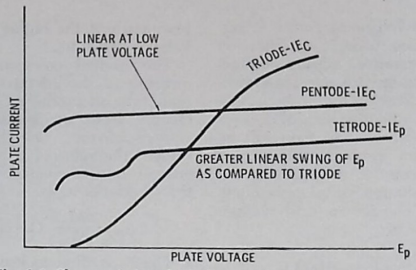


Fig. 6-4. Characteristics of triode, tetrode, and pentode tubes.

ode curve). The triode has good fidelity as an audio amplifier when operated on the linear portion of its transfer characteristic. It has a significant second-harmonic component which limits its efficiency if the second-harmonic distortion is not to exceed a tolerable percentage. Such second harmonics can be suppressed by using two triodes in a push-pull arrangement. In radio-frequency amplifier operation, a triode requires neutralization because of the low-impedance feedback path from plate to grid. Moreover, the triode requires more drive signal than a comparable tetrode or pentode audio or class-C amplifier.

The tetrode has a high plate resistance, and it can have a high g_m. In addition, there is more effective shielding between the plate and grid circuits. Tetrode and pentode tubes are referred to as constant-current generators, because their plate currents are rather constant regardless of changes in plate voltage for a given grid bias. A given change in the grid voltage of a pentode, compared with that of a triode, causes a much greater change in plate current and a greater output. In class-C operation, a good pentode or tetrode normally requires no neutralization except when operated at very high frequencies. Even at high frequencies, only a limited amount of noncritical neutralization is required.

The pentode has a high plate resistance and can be made with a very high g_m. Thus a substantial change can occur in the plate current and plate voltage with only a small change in the applied grid signal. Note from the pentode curve that its performance is linear to a much lower value of plate voltage than a comparable tetrode.

In general, vacuum tubes have high input resistance. For many practical designs, it can be considered infinite in comparison to the impedance of the source of input signal. The plate output resistance of a vacuum tube is also relatively high but much lower than its input resistance. Pentode and tetrode tubes have substantially higher output resistances than a triode. Again, this verifies the logic of considering a triode as a low-impedance, constant-voltage source of signal, while the tetrode and pentode are considered more appropriately a high-impedance, constant-current source of signal.

Since a triode has a low output resistance, a certain level of output voltage can only be obtained with both a greater plate-current variation and a higher dc component of plate current as compared to tetrode or pentode operation. This does not mean that tetrodes and pentodes do not operate with high dc plate current and high ac voltage variations. With comparable levels of current variation, they incorporate an even higher output capability plus a greater power sensitivity. This means that a greater power output can be obtained for a given level of applied signal. Stated another way, more driving power is required for a triode than a pentode for a given level of power output.

129. Define the following terms in reference to vacuum tubes: amplification factor, plate resistance, mutual conductance, and maximum inverse plate voltage.—The amplification factor, or μ, is a measure of the effectiveness of a vacuum tube in producing a plate-voltage change from an applied grid-voltage change. More exactly, it expresses the quotient of a change in plate voltage divided by the change in grid voltage that produces it, or:

$$\mu = \frac{\Delta E_p}{\Delta E_g} \Big| \, (I_p \text{ constant})$$

The gain of a vacuum-tube amplifier can be made to approach but never reach the value of the μ of a given tube. The higher the impedance of the load placed on the output of the tube (providing the appropriate dc operating voltages can be maintained), the more nearly the gain of the associated amplifier approaches the value of μ. It can be said then that over the practical range of operation, the higher the increase in the value of the plate load resistance, provided the proper plate voltage and grid bias are maintained and the tube is operated only over the linear portion of its characteristics, the higher the possible voltage gain becomes, and the nearer the stage gain approaches the value of μ.

The plate resistance is a measure of the influence that a plate-voltage change has on a plate-current change. It can be expressed mathematically as the quotient of a small change in plate voltage divided by the resultant small change in plate current, or:

$$r_p = \frac{\Delta E_p}{\Delta I_p} \Big| \, (E_g \text{ constant})$$

Its value depends on the influence that a changing plate voltage has on the plate current. As compared to a triode, a tetrode or pentode tube with its screen grid affords better isolation, and, therefore, a change in plate voltage has much less influence on the plate current. This means that the plate resistance of a tetrode or pentode is much higher than that of a triode. The more effective the screen-grid voltage is in controlling the plate current, the higher is the plate resistance of a tube.

The mutual conductance, g_m, is a measure of the effectiveness of a vacuum tube in producing a plate-current change from an applied control-grid voltage change. More exactly, it expresses the ratio of a change in plate current to the change in grid voltage that produces it, or:

$$g_m = \frac{\Delta I_p}{\Delta E_g} \Big| \, (E_p \text{ constant})$$

The g_m is often spoken of as the figure of merit of a vacuum tube in conjunction with the interelectrode capacitances. It is a measure of the effectiveness of the grid voltage in producing a substantial change in plate current. Certain tube types are designed with low capacitances and high g_m for use at high frequencies and/or in wideband amplifiers.

The maximum inverse plate voltage is the maximum value of inverse voltage that can be safely applied between the anode and cathode (negative to the anode and positive to the cathode). This value depends on the physical structure, the spacing of the electrodes, and the absence or presence of any form of gas in the tube enclosure.

130. Describe the construction of a beam power tube. In what type of circuits do these tubes find application?—The beam power tube (Fig. 6-5) is a special form of tetrode-pentode with characteristics more like those of a pentode. It provides the ultimate in power sensitivity and absolute value of output power. Beam-forming plates between the screen grid and the plate guide the electrons in an efficient beam-like manner between cathode and plate. Because these plates are at cathode potential, their focusing action sets up a simulated suppressor grid between the screen grid and the plate. Thus, even at low plate voltages there is no flow of secondary electrons from the plate to the screen grid. Such a tube has a high plate efficiency and power sensitivity. Beam power tubes are used widely in audio power stages and throughout the radio-frequency sections of transmitters as os-

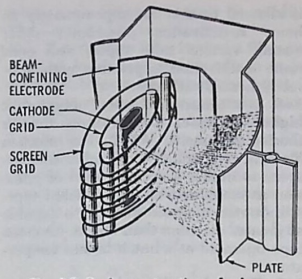


Fig. 6-5. Basic construction of a beam power tube.

cillators and amplifiers. They have the same uses as conventional tetrodes and pentodes but with special emphasis on those applications that require the generation of considerable power output.

131. What is the composition of filaments, heaters, and cathodes in vacuum tubes?—The filament is a thermionic generator of electrons. Certain types of filament wire, usually of thoriated tungsten, emit electrons when heated. These filaments are common in high-power vacuum tubes and tube rectifiers. A heater (Fig. 6-1) is a filament-like structure, too, but it is not used specifically as an electron-emitting surface. Rather, the heat from the heater brings a coated nickel cylinder which surrounds the heater up to an operating temperature which will cause the special coating to emit electrons. This type of cathode is said to be indirectly heated.

The direct-heating filament is usually made of thoriated tungsten. In an indirectly heated cathode, the filament or heater is usually tungsten wire, while the cathode-emitter cylinder is made of nickel with a thorium-oxide coating.

132. What is the primary purpose of the control grid of a triode?—The control grid provides a means of controlling and varying the plate current of a triode. A small grid-voltage change is capable of producing a substantial plate-current change, which can be made to result in an amplified plate-voltage change.

133. What is the primary purpose of the screen grid of a tetrode?—The screen grid minimizes the influence of the plate voltage on the plate current and permits higher efficiency. It also lowers interelectrode capacitances, particularly between the plate and grid, providing more stable operation. In many applications, the tetrode does not require neutralization in radio-frequency amplifier service.

134. What is the primary purpose of the suppressor grid of a pentode tube?—It reduces secondary emission. Operating at or near ground potential, it blocks the undesired movement of electrons from plate to screen grid at low plate voltage. Gain and efficiency are improved. Also, the plate voltage can be made to swing to a lower minimum value without distortion.

135. What is the primary purpose of a screen grid in a vacuum tube?—It permits higher amplification and lower interelectrode capacitances by reducing the influence of the plate voltage on the plate current.

136. What is the primary purpose of a suppressor grid in a multielement vacuum tube?—It reduces secondary emission, permitting a higher gain and efficiency.

137. What is the purpose of a bias voltage on the grid of an audio-frequency amplifier tube?—The grid of a vacuum tube is biased negatively. It is not supposed to attract electrons but only to control their passage through the grid wires on their way to the plate. The bias voltage sets up proper operating conditions, allowing the applied signal to swing both positively and negatively without causing the instantaneous grid voltage to become positive to a level that will attract the electrons of the space charge to the grid itself. Any resultant grid current also lowers the grid input impedance, placing an undesired low-impedance load on the source of signal.

138. What is the space charge in a vacuum tube?—In the normal operation of a vacuum tube, the cathode is able to emit more electrons than the plate can accept. These excess electrons collect in a cloud between the cathode and con-

trol grid. This grouping of electrons is referred to as the space charge. Inasmuch as it is a grouping of electrons, the net charge is negative and offers opposition to the further emission of electrons from the cathode. The control grid, however, is able to influence the electron density of this space charge; the more negative the control grid, the higher is the density. The control that the grid exerts is used to regulate the number of electrons that break away from the cloud and move on to the plate. The less negative the grid is made, the more electrons are pulled out of the space charge and pass on through the grid wires to the plate.

139. What is the meaning of electron emission?—Electron emission is the freeing of electrons from the surface of a material by supplying them with energy from some external source. This external energy can be in the form of heat, light, atomic bombardment, or an electric field.

140. What is the meaning of secondary emission?—In vacuum-tube practice, secondary electron emission usually refers to the emission of electrons from the surface of a material as a result of the energy imparted to them by the bombardment of high-velocity electrons arriving from another source. In a vacuum tube, high-velocity electrons arriving at the plate can free additional electrons from the plate.

141. What is a getter in a vacuum tube?—The getter is used in the construction of a vacuum tube. It is a material that can be flashed by external heat after the tube has been evacuated. This flashing causes it to absorb undesired gases which may persist within the tube.

142. What type of vacuum-tube emitting surfaces respond to reactivation?—At times, thoriated-tungsten filaments are reactivated.

143. Describe how reactivation may be accomplished.—In the reactivation process, the filament voltage is increased to several times the normal value for a specified length of time (1 minute). Then the voltage is reduced to about one-half of this value, and the filament is allowed to heat for approximately an hour. Reactivation procedures differ among various tube types, and even some reactivation is possible with indirectly heated cathodes.

144. Is a tungsten filament operated at higher or lower temperatures than a thoriated filament? Why?—The tungsten filament is operated at a higher temperature to obtain a specific level of emission as compared to the thoriated type. A thoriated-tungsten filament is capable of greater emission than a pure-tungsten type operated at a much higher temperature.

145. What is indicated when a blue glow is noticed within a vacuum-tube envelope?—It is an indication of the presence of gas. The presence of undue gas lowers the efficiency of the vacuum tube and shortens its life.

146. What are the visible indications of a soft tube?—A blue or purple glow within the tube when in operation shows the presence of air or gases within the bulb. Secondary effects are often higher-than-normal plate current, poor efficiency, and instability.

147. Why should the cathode of an indirectly heated type of vacuum tube be maintained at nearly the same potential as the heater circuit?—It prevents spurious signal pickup such as hum, minimizes noise generation, and prevents voltage breakdown between the cathode and filament.

148. Why is it important to maintain transmitting-tube filaments at recommended voltages?—An excessive operating voltage reduces tube life. Insufficient filament voltage results in reduced emission and inefficient operation of the tube.

149. Why is it desirable to use an alternating-current filament supply for vacuum tubes?—The advantage is a practical one because of the simplicity of using a filament transformer. In most practical applications, a suitably designed circuit will result in a minimal pickup of ac hum when an ac filament supply is used.

150. Why is it advisable to reverse the polarity of the filament potential of high-power vacuum tubes periodically

when a dc filament supply is used?—The filament life is extended.

151. If a vacuum tube having a filament rated at ¼ ampere and 5 volts is to be operated from a 6-volt battery, what is the value of the necessary series resistor?—This is an Ohm's law problem. If 5 volts is to be present across the filament, it is necessary that one volt be present across the series resistor. Inasmuch as the current is known and is the same in any part of a series circuit, it is possible to determine the value of the required resistor as follows:

$$R = \frac{E}{I} = \frac{6-5}{0.25} = \frac{1}{0.25} = 4 \text{ ohms}$$

152. Draw a graph indicating how the plate current in a vacuum tube varies with plate voltage, grid bias remaining constant.—Such a graph for a triode is shown in Fig. 6-6. Initially, the plate current rises slowly with an increase in plate voltage; then it begins to rise faster and at a linear rate.

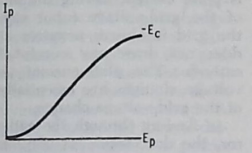


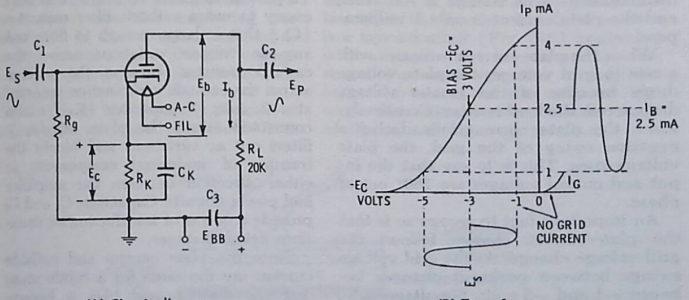
Fig. 6-6. Plate current versus plate voltage with grid voltage constant (triode tube).

153. What are cathode rays?—A cathode ray is a stream of electrons, usually of high velocity, pulled from a heated cathode under the attraction of a high voltage. The high-speed electrons coming from the cathode of an oscilloscope, radar, or television picture tube are referred to as cathode rays.

OPERATION

154. Draw a diagram of a resistance load connected in the plate circuit of a vacuum tube, and indicate the direction of electron flow in this load.—Refer to Fig. 6-7A.

155. Explain the operation of a triode vacuum tube as an amplifier.—In a vacuum-tube amplifier (Fig. 6-7A), the dc voltage (E_b) attracts the electrons emitted from the cathode. The number of electrons reaching the plate and flowing through the plate-load resistor (R_L) is determined by the negative voltage applied to the control grid. In this circuit, the plate current (I_b) in flowing through the cathode resistor (R_K) develops a potential of 3 volts dc across the cathode resistor-capacitor combination. The direction of the plate current through the cathode resistor is such that the grid is made negative with respect to the cathode by 3 volts.



(A) Circuit diagram. (B) Transfer curve.

Fig. 6-7. Triode voltage amplifier.

The transfer curve of Fig. 6-7B shows that the plate current is a function of the negative grid voltage. Notice that over the most linear portion of the curve (between −1 and −5 grid volts), the plate current changes linearly with respect to the grid voltage. The negative dc bias is usually at the center of the linear portion of the transfer characteristic (−3 volts in the example). With this amount of negative grid bias supplied to the vacuum-tube stage, the dc component of plate current (in this example) is 2.5 milliamperes. This is referred to as the operating-point plate current.

To understand the operation of the triode as an amplifier, assume that an ac sine wave (E_s) of 2 volts peak is being applied to the control grid. As the sine wave rises on its positive crest, the negative grid voltage decreases, and the plate current increases. At the crest of the positive alternation, the instantaneous grid voltage is −1 volt, and the plate current is 4 milliamperes. The less negative the grid is driven, the weaker the space charge is and the more freely the electrons flow between cathode and plate.

On the negative alternation of the applied signal, the grid voltage swings in the negative direction. Consequently, the plate current decreases, because the more negative grid has a greater holding power on the space-charge electrons. At the crest of the negative alternation, the instantaneous grid voltage is −5 volts, and the plate current is only 1 milliampere.

When the plate current increases with a rise in grid voltage, the plate voltage drops because of the greater voltage drop across the load resistor. Conversely, when the plate current falls during a negative swing of the grid, the plate voltage rises. This is to say that the input and output voltages are 180° out of phase.

An important fact to recognize is that the plate-current change follows the grid-voltage change. As the grid voltage swings between peaks, it changes between −1 and −5 volts. Simultaneously, the plate current also changes between the limits of 4 milliamperes and 1 milliampere. Thus the peak-to-peak ac plate current is 3 milliamperes (or 1.5 mA peak), which flows in the 20,000-ohm plate-load resistor (R_L).

The plate-voltage change can be determined by multiplying the plate current times the ohmic value of the plate-load resistor, or:

$$E_p = I_p R_L = 0.0015 \times 20{,}000$$
$$= 30 \text{ volts}$$

The plate-voltage change is 30 volts peak. Inasmuch as the initial grid-voltage change was 2 volts peak, the amplifier has a gain of 30/2, or 15.

This is how a triode vacuum tube functions as a voltage amplifier. By correct selection of tube and operating conditions, a vacuum-tube stage can also be made to operate as a power amplifier.

In the example of Fig. 6-7, the stage is said to operate class-A, because there is plate current during the entire cycle of the grid-voltage input signal. Also, the grid is always negative and hence does not draw any current from the cathode. The plate-current and plate-voltage changes are essentially replicas of the grid-voltage change.

In flowing through the cathode resistor, the dc component of plate current I_b develops the required dc bias for the tube. This bias is such that the operating grid bias is at the center of the most linear portion of the transfer characteristic. To prevent negative feedback, it is necessary to use a cathode filter capacitor (C_K) that is large enough to filter out any ac voltage variations across the cathode resistor, keeping the voltage across the cathode combination constant at −3 volts. A capacitor (C_3) is also connected across the plate supply. It filters out ac variations and blocks the transfer of undesired components in either direction between the amplifier and power circuits. Capacitors C_1 and C_2 provide a means of transferring ac variations between stages.

Since the plate current and cathode current are the same for a triode stage and the desired grid bias is known, Ohm's law can be used to determine the value of the cathode resistor:

$$R_K = \frac{E_K}{I_K} = \frac{3}{0.0025} = 1200 \text{ ohms}$$

The stage is referred to as a grounded-cathode amplifier because the cathode is at ac ground potential. If the cathode capacitor were not present, the cathode would not be at exactly ac ground potential because of the ac voltage drop that would appear across the cathode resistor. Such a stage would still be considered a grounded-cathode amplifier. The small ac variation across an unbypassed cathode resistor provides a form of negative feedback.

156. Describe the characteristics of a vacuum tube operating as a class-A amplifier.—A class-A amplifier is so biased (Fig. 6-7B) that plate current is present during the entire cycle of the grid-voltage input signal. The bias is chosen at a point on the linear portion of the transfer characteristic such that the plate-current change and consequent plate-voltage output follow the input change of the grid voltage with minimum distortion. In a class-A amplifier, the grid is always negative and does not draw any current from the cathode. Therefore no grid driving power is required. A class-A amplifier is noted for its low distortion, low efficiency, and low power output as compared to other classes of amplifiers. Triode class-A amplifiers operate with lower efficiency than tetrode or pentode class-A amplifiers.

157. Does dc grid current normally flow in a class-A amplifier employing one tube?—No. In class-A operation there is no grid current because the grid voltage is held negative during the entire cycle of the input wave.

158. Is the dc bias normally positive or negative in a class-A amplifier?—It is negative. The bias is made negative enough to obtain linear operation, and the signal is held to a level such that its positive peak value does not drive the grid-cathode potential positive.

159. What is the effect of incorrect grid bias in a class-A audio amplifier?—Improper biasing produces a distorted output. Improper biasing can also establish improper dc operating conditions in the vacuum tube which could cause excessive power dissipation or result in inefficient operation of the tube and stage.

160. What circuit and vacuum-tube factors influence the voltage gain of a triode audio-frequency amplifier stage?—The voltage gain of a triode amplifier depends on the amplification factor (μ) and plate resistance of the tube as well as the external load resistance. In equation form:

$$A_v = \frac{\mu R_L}{r_p + R_L}$$

This assumes the application of proper filament potential, positive dc plate voltage, and negative dc grid bias.

TRANSISTORS

161. Describe the physical structure of two types of transistors and explain how they operate as an amplifier.—The two common transistor types are junction bipolar and field-effect (FET). The first type of transistor developed, seldom used today, is known as the point-contact type. The junction bipolar transistor is a layered affair (Fig. 6-8) beginning with a small wafer known as the substrate. For most transistor types, this layer also serves as the collector element. This initial wafer is usually made of silicon, sometimes germanium.

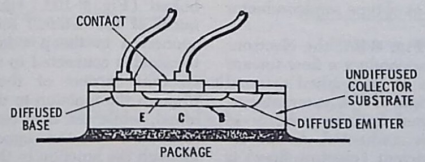


Fig. 6-8. Basic structure of bipolar junction transistor.

The two additional elements of a transistor, emitter and base, are then diffused into the wafer. Such a wafer, only a tiny fraction of an inch in diameter, is then sliced into individual transistors, producing as many as 20,000 of these tiny devices.

Note that in an individual transistor there are two boundaries, one between the collector and the base and the second between the base and the emitter. The understanding of transistor operation depends on the knowledge of what takes place at these two junctions between semiconductor material. The first step is to understand the operation of a simple two-element semiconductor device. This idea is used in the construction of semiconductor detectors and rectifiers.

A semiconductor is an in-between crystalline material that cannot be classified as either a conductor or an insulator. However, with the application of appropriate external force, one can establish a controlled motion of charges in a semiconductor material. The two most common forms of semiconductor materials used in transistors are silicon and germanium.

The two common forms of semiconductor material according to electrical characteristics are n-type and p-type. Small amounts of impurities are added to the basic germanium or silicon semiconductor. One type of impurity results in the formation of electron carriers within the material, and therefore a semiconductor containing this type of impurity is known as n-type semiconductor. Conversely, another type of impurity is such that the motion of charges is in the form of holes, or positive charges, rather than electrons. A semiconductor containing this type of impurity is known as p-type semiconductor material.

As shown in Fig. 6-9A, the electrons in the n-type semiconductor flow toward the positive side of an applied external emf. The direction of the external current is determined by the polarity in which the emf is connected. As the arrows indicate, current (electron flow) is from the negative to the positive side of

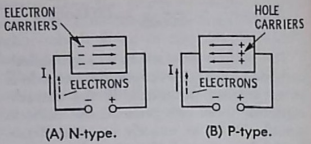


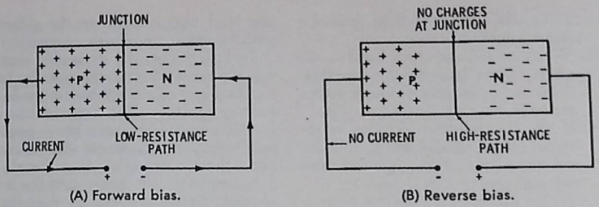
Fig. 6-9. Charge motion in semiconductor material.

the applied voltage. Reversing the polarity of the applied voltage causes a change in the direction of current in the external circuit and through the semiconductor material.

In p-type semiconductor material, the current carriers are holes, or positive charges. Their direction of motion is opposite to that of electrons (Fig. 6-9B). Therefore, the hole current is toward the negative side of the applied voltage. The direction of current is again a function of the polarity of the external voltage.

The resistance of semiconductor material falls between that of a conductor and a nonconductor (insulator). The actual resistance depends very much on the number of current carriers (electrons or holes) in the semiconductor material. The number of these free carriers depends on the percentage of a specified impurity that has been added to the pure crystalline structure. This is referred to as doping the pure semiconductor material. The greater the doping, the more carriers there are, and the lower is the resistance of the semiconductor material.

When two sections of semiconductor material of opposite type are combined to form a junction, they provide rectifier action and a unidirectional current. When the junction is said to be forward biased (Fig. 6-10A), the positive terminal of the external source of emf is connected to the p side; the negative terminal is connected to the n side. The electron carriers of the n side flow through the junction to the positive terminal, while the hole carriers of the p side flow in the opposite direction through the junction to the negative terminal. The junction now has a low re-



(A) Forward bias. (B) Reverse bias.

Fig. 6-10. Semiconductor diode operation.

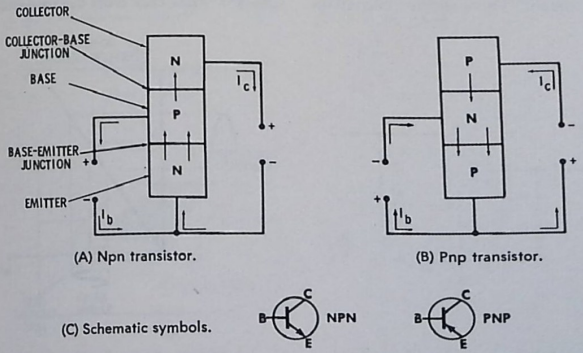
sistance, and a significant external current is present in the circuit. If the junction is back biased, or reverse biased, as in Fig. 6-10B, the electron carriers of the n side move to the positive terminal, and the hole carriers of the p side move to the negative terminal. There is no motion of carriers across the junction, and the resistance of the junction is high. Very little or no external current is present.

In summary, the junction acts as a rectifier. When it is forward biased, there is a strong external current; when it is reverse biased, there is no external current. Thus the simple pn junction can be used as a rectifier or a detector.

When two junctions are a part of the semiconductor structure, a bipolar transistor is formed and can be used as a voltage or current amplifier. In the construction (Fig. 6-11), note that the center segment is a different type of semiconductor than the two outer segments. In Fig. 6-11A, the outer sections are n type and the center section is p type. This is referred to as an npn transistor. The center segment is called the base, and the outer segments are called the emitter and the collector. Conversely, a pnp transistor (Fig. 6-11B) has n-type material for the center segment.

The following four factors are important in understanding the operation of the bipolar-transistor circuit:

1. In an operating circuit, the collector-base junction is reverse biased.



(A) Npn transistor. (B) Pnp transistor.

(C) Schematic symbols.

Fig. 6-11. Transistor biasing and basic operation.

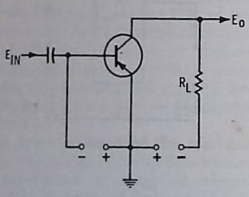
Thus the collector-base junction has a high resistance.

2. When no voltage (zero bias) is applied to the base-emitter junction, there is no current through either junction.
3. If the base-emitter junction is reverse biased, it also has a high resistance. Again there is no current through either junction.
4. When the base-emitter junction is forward biased, as it is in normal operation, there is a motion of charges across the base-emitter junction; its resistance is low. Activity within the transistor is such that there is an amplified current crossing the base-collector junction. In a normal circuit, the collector current is higher than the base current, and the transistor stage can be operated as a current amplifier and, with an appropriate external circuit, as a voltage amplifier as well.

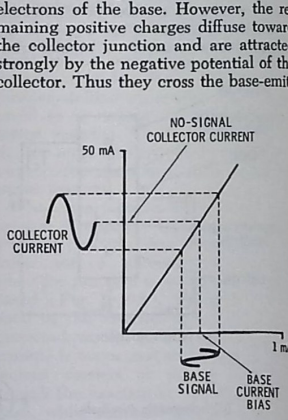
Consider now the activity that takes place when, in normal operation, the base-collector junction is reverse biased and the base-emitter junction is forward biased. A small amount of signal-current variation in the base circuit causes a substantially larger variation in the collector current. This collector current in the load circuit between the collecto and the emitter produces an output.

In Fig. 6-11A, the dc supply source apply a reverse bias to the collector-bas junction and a forward bias to the base emitter junction. The forward bias o the base-emitter junction forces positiv and negative charges to the junction and a base current (I_b) is produced. A a result, electrons move into the bas element. Some of them are neutralize by the positive charges (holes) in th base. However, more electrons mov into the base than there are neutralizin holes. These are diffused to the collecto junction. Because of the positive poten tial of the collector, there is a stron flow of electrons from the emitter int the collector through the base. This flo is much stronger than the base current

A similar activity occurs in a pn transistor; pnp and npn transistors ar said to have complementary character istics. In the case of the pnp transisto the forward biasing of the base-emitte junction causes a rush of positiv charges across the base-emitter junctio because of the low-resistance path These are in part neutralized by th electrons of the base. However, the re maining positive charges diffuse towar the collector junction and are attracte strongly by the negative potential of th collector. Thus they cross the base-emi



(A) Circuit diagram.



(B) Graph of operation.

Fig. 6-12. Basic transistor-amplifier stage.

ter junction in quantity and move through the base, across the collector-base junction, and into the collector region. Again, there is a strong component of collector current.

In the pnp circuit, current is in the opposite direction from that of the npn type. Note that a negative potential must be applied to the p-type collector material in order to bias the collector-base junction. Therefore, the motion of electrons in the external circuit is in the opposite direction compared to the direction in the npn circuit.

The previous discussion considered the dc activity in the transistor. An applied audio or other signal causes the base current to vary about the base bias current set by the base bias voltage (Fig. 6-12). This base-current variation in turn causes an amplified change in the collector current. The ratio of the ac collector current to the ac base current is the small-signal beta of the transistor stage, or:

$$\beta = \frac{\Delta I_C}{\Delta I_B}$$

The output voltage, E_o, results from the variations of the collector current in the collector load. The input base-current variation is caused by the input voltage, E_{in}. The voltage gain of the transistor stage is the ratio E_o/E_{in}.

A second common type of transistor is the field-effect transistor (Fig. 6-13). It consists of a single junction and but one polarity of charge carrier, and it is known as a unipolar device. In contrast, the bipolar transistor has two junctions, and both polarities of carriers (electrons and holes) are essential to its operation. The junction field-effect transistor consists of a bar of p- or n-type silicon semiconductor. A thin region of semiconductor of opposite sign is placed above or wrapped around the bar. The bar is called a channel, and the element that controls the motion of charges along the channel is known as the gate.

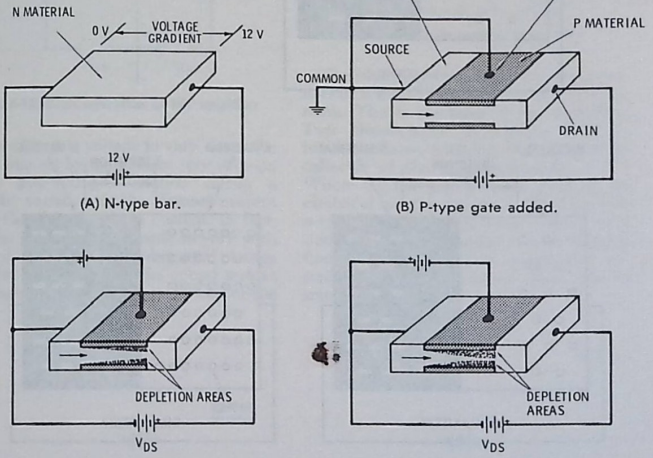


Fig. 6-13. Structure and basic operation of field-effect transistor.

The common end of the channel is called the source, and the opposite end is named the drain.

You have learned that when a junction is reverse biased there is no significant motion of charges across the junction. However, as shown previously in Fig. 6-10B, there is a rearrangement of the electrons and hole carriers. They draw away from the junction, establishing a neutral depletion area. An increase in the reverse bias, as shown in Fig. 6-14B, widens the depletion area. The width of the depletion area in both the p and n sections also depends on the number of carriers within the area. Thus by proper doping it is possible to control the relative number of excess charges per volume. The actual depletion area is smaller for a heavily doped material than for one of fewer charge carriers, as shown in Fig. 6-14C.

A junction exists between the gate and the channel of the junction FET. The bias applied to the gate controls the charge motion in the channel. The motion of charges is from source to drain through the channel. When there is zero bias between gate and source (Fig. 6-13B), the application of a positive

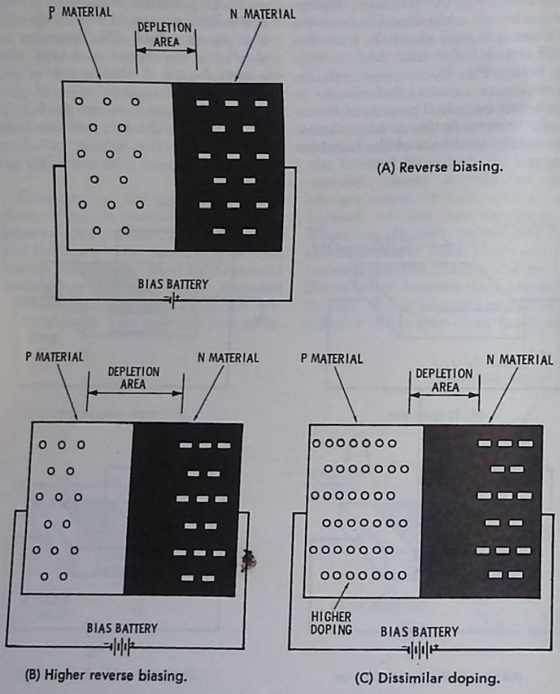


Fig. 6-14. Influence of biasing and doping on depletion area.

voltage between drain and source causes the electron carriers of the channel to move between source and drain. As the positive voltage is increased, this current rises. In effect, the channel acts as a controlled resistor.

When the junction is reverse biased, a depletion region extends into the channel (Fig. 6-13C). The presence of the depletion region in the channel cause an increase in the resistivity of the bar (decrease in conductivity). By increasing the gate bias, there is a further rise in the channel resistance, and the motion of charges (drain current) is reduced (Fig. 6-13D). If the gate bias voltage is made high enough, the channel current, or drain current, can be reduced to zero (cut off).

An applied audio or other signal

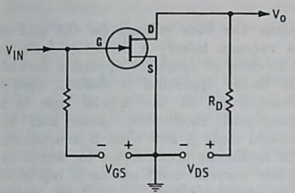


Fig. 6-15. Basic operation of FET amplifier.

causes the gate voltage to vary about the gate bias set by the gate-battery voltage. This gate-voltage variation causes a similar variation in the channel current and therefore the drain current. In fact, as the gate voltage is made to vary with signal, there results a substantial change in the drain current. The actual output voltage results from the variations of the drain current in the load resistor (R_D in Fig. 6-15). The actual voltage gain of the stage is the ratio V_o/V_{in}.

The positive swing of the gate voltage produces an increase in the drain current. In turn, there is a drop in the drain voltage (the output voltage swings in the negative direction). Conversely, the negative alternation of the input voltage decreases the drain current, and there is a positive-going swing of the drain and output voltage. The input and output voltages are said to be of opposite polarity, or out of phase.

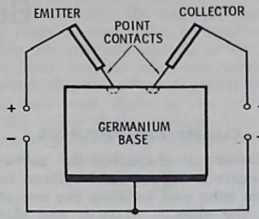


Fig. 6-16. Point-contact transistor.

The older point-contact transistor consists of a single tiny bit of n-type germanium. This is the base of the transistor. Two close-spaced catwhisker contacts touch the base, forming the emitter and collector of the transistor (Fig. 6-16). Where the two points make contact, the electrical biasing causes a tiny region of p-type germanium activity. The formation of a pnp transistor results. Operation is similar to that previously described for the junction pnp bipolar transistor.

CHAPTER 7

Basic Amplifiers and Classes, Element 6

CLASSES AND AMPLIFIERS

162. Draw a characteristic curve of plate current versus grid voltage for a vacuum tube and indicate the operating points for class-A, class-B, and class-C amplifier operation.—Refer to Fig. 7-1. In a class-A amplifier, the output plate current is a replica of the input voltage. Plate current flows during the entire cycle of the input voltage wave. In normal practice, a class-A amplifier is biased to the center of the linear portion of the tube transfer characteristic.

A class-B amplifier is biased at cutoff. Thus, with an applied input sine wave, the tube conducts only during the positive alternation of the input wave; that is, plate current occurs for only 180° of the input wave.

In class-C amplifier operation, the tube is biased beyond cutoff. As a result, plate current occurs for only a portion of the positive alternation of the input wave. In a typical class-C amplifier, plate current may occur for only 90° to perhaps 150° of the input cycle. Frequently, a class-C amplifier is biased to two times the value of the cutoff bias. For example, if cutoff is −12 volts, class-C bias would be set near −24 volts.

163. What are the factors that determine the bias voltage for the grid of a vacuum tube?—A dominant factor is the class of amplifier operation desired. If linear operation is desired, class-A biasing or, in the special case of a push-pull connection, some bias between class A and class B is necessary. In nonlinear applications for which the plate current need not be a replica of the input voltage, class-B or class-C amplifier operation can be used to obtain higher efficiencies.

The actual biasing is also influenced by two other factors. These are the level of the input signal and the electrode voltages. For example, a triode operating at a low plate voltage has a cutoff bias that is lower in negative value than if the tube were operated with a high plate voltage. Biasing must be such that it accommodates the magnitude of the input signal. In some cases, a weaker input signal permits the bias point to be moved up or down the linear portion of the characteristic to a position that will produce a higher gain or other favorable characteristic. If the input signal sweeps over the complete linear range, the stage is biased to the center of the linear portion of the transfer characteristic. Both plate dissipation and the absence of, or safe level of, grid current are also considerations.

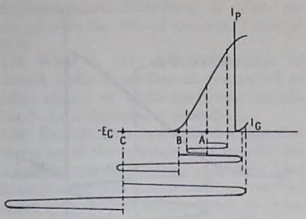


Fig. 7-1. Class-A, -B, and -C bias.

164. What is the approximate efficiency of a class-A vacuum-tube amplifier? Class-B? Class-C?—Efficiences are 20-30%, 35-60%, and 70-85%, respectively, for well designed stages. Efficiencies can be made lower to meet specific design requirements, but they are seldom found higher than the maximum values indicated.

165. What is meant by the load on a vacuum tube?—The load is the resistance or impedance to which an electronic device delivers its power. It can be the plate load resistor of a voltage amplifier, the voice coil of a loudspeaker, the grid circuit of a class-C power amplifier, the antenna impedance to which the transmitter is delivering power, etc.

166. What is the meaning of the term "maximum plate dissipation?"—It is the maximum power that the plate can dissipate safely as heat on a long-term basis.

167. What is the meaning of plate saturation?—Plate saturation refers to the plate current that exists when the cathode surface is delivering to the plate the maximum number of electrons that it can emit. Plate saturation has also come to mean the level of the plate current when a further rise in grid voltage for a given operating condition produces no further increase in plate current.

168. What is the most desirable factor in the choice of a vacuum tube to be used as a voltage amplifier?—In a triode voltage amplifier, the amplification factor (μ) is the important factor. Possible voltage gain is related directly to the μ.

For multielement tubes and wideband amplification, the mutual conductance (g_m) is of primary concern. For this type of tube, the g_m determines just how mush plate-current change is present to develop plate-voltage output.

For wideband applications the factors are the g_m and the input-output capacitances.

169. Explain how you could determine the value of cathode bias resistance necessary to provide correct grid bias for any particular amplifier.—The grid bias is the product of cathode resistance times cathode current ($I_K R_K$). In the case of a triode, the cathode current is the plate current only. In multielement tubes, the cathode current is the sum of the plate current plus the screen-grid current plus any other electrode currents that may exist. Refer to the calculation of the value of the cathode bias resistance in question 155 (Chapter 6). The equation for cathode resistance is:

$$R_K = \frac{E_C}{I_K}$$

where,

R_K is the cathode bias resistance in ohms,
E_C is the required bias voltage in volts,
I_K is the cathode current in amperes.

170. Given the following vacuum tube constants: $E_P = 1000$ volts, $I_P = 150$ mA, $I_G = 10$ mA, and grid leak $= 5000$ ohms, what would be the value of dc grid bias voltage?—The dc grid bias voltage in this case would be the product of the grid resistor (grid leak) in ohms times the current through this resistor, which is the grid current only. Therefore:

$$E_C = I_G R_G = 0.010 \times 5000 = -50 \text{ volts.}$$

171. What is meant by a blocked grid?—Although the control grid of a vacuum tube is a mesh that permits electrons an easy passage between wires as they flow between cathode and plate, some electrons do strike the grid wires. If there is no path for these electrons in the external grid circuit, they begin to accumulate on the grid structure and

develop a negative charge. This charge can build so high that it blocks further emissions of electrons from the cathode, causing the plate current to drop to zero. This condition is known as a blocked grid.

172. Why is correct grid bias important in an audio-frequency amplifier?—Proper biasing is important if linear, nondistorted amplification is desired. Proper biasing permits the amplifier to accommodate the level of the input signal and, at the same time, permits the stage to operate efficiently and deliver the most output without exceeding its safe plate dissipation. As has been mentioned in the answers to previous questions, the grid bias value also determines the class of operation.

173. Does a properly operated class-A amplifier produce serious modification of the output waveform.—No. Operation is made linear by proper choice of bias, and the output voltage is a good replica of the input voltage waveform.

174. What is the maximum permissible rms value of audio voltage which can be applied to the grid of a class-A audio amplifier which has a grid bias value of −10 volts?—Class-A amplifiers, in general, are operated in such a manner that the grid is never driven positive. With a bias of −10 volts, the instantaneous grid voltage will rise to zero volts when the applied signal has a peak value of 10 volts (Fig. 7-2). The rms value becomes:

$$E_{rms} = 0.707 \times E_p$$
$$= 0.707 \times 10 = 7.07 \text{ volts}$$

175. List four causes of distortion in a class-A audio amplifier.—Some causes of distortion are improper grid bias, too high a level of input signal (overdrive), improper load, improper electrode dc voltage, a leaky or failing tube, improper supply-line filtering, improper load impedance, and introduction of hum or some other spurious signal or oscillation.

176. Name four applications for vacuum-tube operation as a class-A amplifier.—Class-A amplifiers can be used as audio or video voltage amplifiers, audio or video power amplifiers, radio-frequency amplifiers (tuner and i-f systems of receivers), speech amplifiers and modulators, and test-instrument amplifiers.

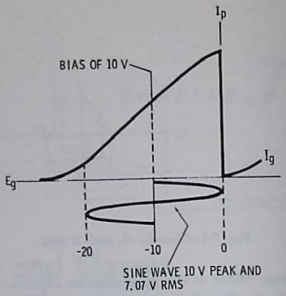


Fig. 7-2. Bias and input signal level for class-A stage.

177. What is the dc plate voltage of a resistance-coupled amplifier stage which has a supply voltage of 260 volts, a plate current of 1 milliampere, and a plate load resistance of 100,000 ohms?—The plate voltage is always the plate supply voltage less whatever voltage drop exists across the plate load resistance, or:

$$E_B = E_{BB} - E_{RL}$$

The voltage drop across the plate load resistance is the product of that resistance times the current in the resistance, or:

$$E_{RL} = I_P \times R_L = 0.001 \times 100{,}000$$
$$= 100 \text{ volts}$$

The plate voltage becomes:

$$E_B = 260 - 100 = 160 \text{ volts}$$

178. How may even-harmonic energy be reduced in the output of an audio-frequency amplifier?—The two important factors are proper biasing and the selection of an input signal that varies only over the most linear portion of the transfer characteristic and does not swing into the curved regions of the characteristic, particularly near cutoff.

Even-harmonic distortion is also reduced with the use of push-pull amplifiers.

179. What is the chief advantage of class-A audio operation as compared to other classes of audio-frequency amplifiers?—Low-distortion operation.

180. Explain how you would determine the value of the cathode bias resistor for a specific amplifier stage.—Cathode bias is always the product of cathode current times cathode resistance. Refer to questions 155 (Chapter 6) and 169. In a class-C amplifier, safety bias is often in the form of cathode bias that limits the plate current to a safe value in case rf excitation is lost.

181. Draw a simple schematic diagram of a triode vacuum-tube audio-frequency amplifier inductively coupled to a speaker.—See Fig. 7-3.

182. Draw a simple schematic diagram showing a method of resistance coupling between two triode vacuum tubes in an audio-frequency amplifier.—See Fig. 7-4.

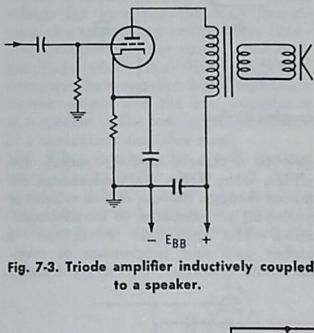


Fig. 7-3. Triode amplifier inductively coupled to a speaker.

183. Draw a simple schematic diagram showing a method of transformer coupling between two triode vacuum tubes in an audio-frequency amplifier.—See Fig. 7-5.

184. Draw a simple schematic diagram of a method of impedance coupling between two vacuum tubes in an audio-frequency amplifier.—See Fig. 7-6.

185. Draw a simple schematic diagram showing a method of coupling a high-impedance speaker to an audio-frequency amplifier without the presence of tube plate current through the speaker windings and without the use of a transformer.—See Fig. 7-7.

186. What would be the effect of leakage in the coupling capacitor in a conventional resistance-coupled audio-frequency amplifier?—When there is a leaking coupling capacitor, the supply voltage from the preceding stage reaches the grid of the succeeding stage. This results in improper biasing of the succeeding stage, producing a distorted output. Plate current becomes high, and there may be grid current along with a loss of gain. Safe plate dissipation may be exceeded.

187. What is the purpose of the decoupling networks in the plate circuits of a multistage audio amplifier?—They prevent feedback. Oscillations and low-frequency relaxation oscillations (called motorboating) are avoided.

188. What is the principal advantage of transformer coupling compared to re-

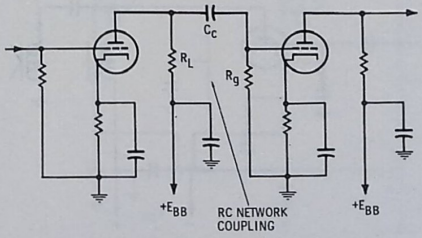


Fig. 7-4. Resistance-coupled triodes.

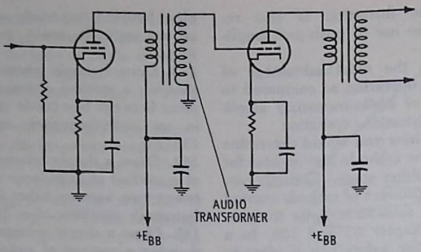


Fig. 7-5. Transformer-coupled audio stages.

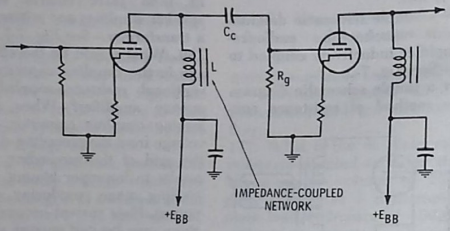


Fig. 7-6. Impedance-coupled triodes.

sistance coupling as used in audio-frequency amplifiers?—Such a connection operates as an efficient power amplifier and also has the capability of a higher voltage gain. A secondary benefit of transformer coupling is the isolation of the dc components and currents.

189. **In a class-A audio-frequency amplifier, what is the main advantage obtained through the use of two triodes in push-pull as compared to parallel operation?**—The principal advantage is higher gain and suppression of even-harmonic distortion. Secondary benefits

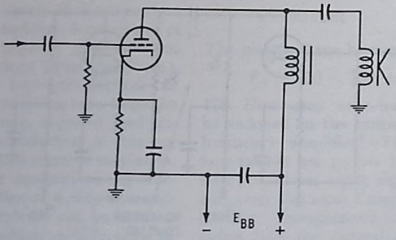


Fig. 7-7. Coupling to a high-impedance speaker.

are less hum and less critical transformer design in terms of core saturation and frequency-response characteristics.

190. Why is a push-pull audio-frequency amplifier preferable to a single-tube stage?—It has a higher output and less even-harmonic distortion. The output capability is double or a bit more compared to the maximum level of a single-tube stage.

191. Draw a simple schematic diagram showing a method of direct coupling between two stages of an audio-frequency amplifier.—See Fig. 7-8.

192. What is the principal advantage of a tetrode over a triode as a radio-frequency amplifier?—The tetrode requires no neutralization in most applications.

193. Why is an audio transformer seldom employed as the output device to be used in the plate circuit of a tetrode audio amplifier stage?—A tetrode has a high output impedance, and no transformer is needed to step up the output voltage for matching the high impedance of a succeeding audio stage. However, transformers are used in the output stage when there must be transformation between the high-impedance tetrode output and the low impedance of a speaker or the low input impedance of a modulated amplifier stage.

194. What is meant by a soft vacuum tube?—Normally the term "soft tube" refers to a defective gassy tube, meaning that gas is present within the evacuated bulb. Such gas shortens the life of the tube, and it produces higher than normal current and erratic operation of the tube.

195. What factors may cause low plate current in a vacuum-tube amplifier?—Some factors are a failing tube with low emission, low filament voltage, or an improper electrode voltage such as too much bias or too low a screen or plate voltage.

196. When an alternating-current filament supply is used, why is a filament center tap usually provided for the vacuum-tube plate and grid return circuits?—This center tap prevents a power-frequency variation (hum) in the desired signal.

197. What currents will be indicated by a milliammeter connected between the center tap of the filament transformer of a tetrode and negative high voltage (ground)?—All tube currents find a ground through this path. Therefore, the meter will indicate plate current and screen-grid current as well as control-grid current if it exists.

CLASS-B OPERATION

198. Describe the characteristics of a vacuum tube operating as a class-B amplifier.—As compared to class-A operation, a class-B stage, biased at cutoff, operates at a higher efficiency and delivers more output. Plate current is present only during the positive alternation of the input wave, producing a distorted

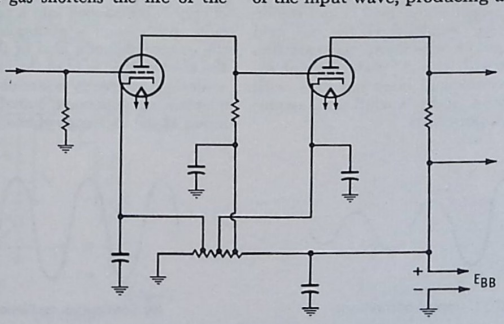


Fig. 7-8. Loftin-White dc coupling.

output. To obtain linear operation from class-B biasing, it is necessary to use two tubes in push-pull. In such an arrangement, one tube conducts during one alternation, and the other tube conducts during the opposite alternation. As a result, the push-pull output is capable of forming a signal that is a good replica of the input wave.

Radio-frequency amplifiers can also be operated class-B, in which case the output resonant tank circuit recovers one alternation of the output, and a linear copy of the input rf wave is obtained. Such a stage is called a class-B linear rf amplifier.

199. Why is it necessary to use two tubes in a class-B audio amplifier?—To obtain linear operation; refer to the previous question.

200. In the operation of a class-B audio amplifier stage, should the plate current fluctuate, or should it remain at a steady value?—The plate current will fluctuate with the variations of the input audio signal. This is a normal condition because the stage is biased near cutoff and there is little or no no-signal plate current. When a signal is applied, the plate current rises from cutoff according to the signal magnitude. Consequently, the average or dc component of plate current rises and falls in accordance with the average amplitude of the input audio signal.

This is not the case for a class-A stage, in which there is an equal swing of plate current above and below the dc plate current established by the grid bias. In class-A operation, the variation is symmetrical; the dc plate current remains constant and does not vary with the incoming audio variations (assuming linear operation).

201. During which portion of the excitation-voltage cycle does plate current flow when a tube is used as a class-B amplifier?—Plate current is present only during the positive alternation of the input wave. Since the tube is biased at cutoff, the negative swing of the input signal below cutoff produces no plate current.

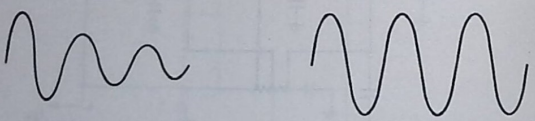
202. What are the effects of overexcitation of the grid circuit of a class-B amplifier?—The resultant nonlinear operation produces peak clipping and results in a distorted output. Grid and plate current swings are abnormally high resulting in poor efficiency. The safe dissipation limits at the control grid, screen grid, or plate may be exceeded.

205. What is the correct value of negative grid bias for a vacuum tube of the following characteristics when operated as a class-B amplifier? Plate voltage, 1000 volts; plate current, 127 mA; filament voltage, 4 volts; filament current, 5.4 amperes; mutual conductance, 8000 micromhos; amplification factor, 25.—For a triode, the cutoff bias is set mainly by the plate voltage and amplification factor in the following manner:

$$E_{cutoff} = \frac{E_b}{\mu} = \frac{1000}{25} = -40 \text{ volts}$$

CLASS-C AMPLIFIERS

204. What is meant by shock excitation of a circuit?—When a burst of electrical energy is introduced into a resonant circuit, that energy is exchanged between the electromagnetic field of the coil and the electrostatic field of the capacitor. In so doing, the energy is stretched out into a series of sine-wave variations. Inasmuch as the exchange of energy encoun-



(A) Damped oscillations. (B) Continuous oscillations.

Fig. 7-9. Shock excitation of a resonant circuit.

ters some resistance, each cycle becomes lower in amplitude than the previous one (Fig. 7-9A). This oscillation continues even though the source of energy has been removed. The number of damped oscillations that occur depends on the Q of the resonant circuit; the higher the Q, the greater is the number of oscillations.

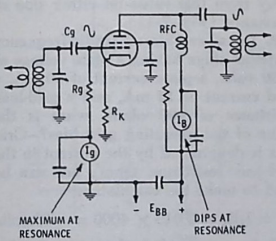
If energy is introduced into the resonant circuit on a cyclic basis, as it is by bursts of plate current applied to the resonant circuit of a class-C amplifier, oscillations will continue to be produced and will be of constant amplitude as in Fig. 7-9B.

205. What is meant by the flywheel effect of a tank circuit?—This is the ability of a resonant circuit to produce a sine-wave circulating current and parallel voltage even though energy is introduced in the form of current peaks or bursts. In effect, the electrical energy is stretched out in the form of a sine wave or series of sine waves even though the source energy is switched on for a comparatively short interval of time. It is this characteristic that permits a class-C amplifier to deliver a sine-wave output even though the tube is switched on for only a short burst of plate current.

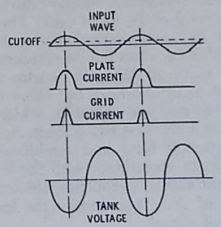
206. Describe the characteristics of a vacuum tube operating as a class-C amplifier.—A class-C amplifier is one that conducts plate current only during a portion of the positive alternation of the input wave. The class-C stage is biased beyond cutoff and permits plate current to pass for only about 120-150° of the complete input cycle. Such a class of amplifier has a high efficiency of up to 80% and occasionally higher. Actual biasing is typically two or more times the cutoff value. The plate-current variation is in the form of short bursts of energy. However, with the selection of a proper Q, a nondistorted sine wave is developed across the output because of the flywheel effect of the output resonant circuit.

As shown in the waveforms of Fig. 7-10B, the tube draws plate current only during the most positive portion of the positive alternation of the input wave. Thus the plate current drawn in bursts is of high peak value. Such a burst supplies a relatively large amount of electrical energy into the plate resonant tank circuit quickly, and the capacitor is charged to a high negative value (sharp drop in plate voltage). However, a resonant circuit has smoothing and energy-storing abilities. When the plate-current burst ceases, the charge on the capacitor begins to fall off, and energy is transferred to the coil. After the charge falls to zero, the collapsing field of the coil releases its stored energy back into the tank circuit. A current of opposite direction results and charges the capacitor in the opposite polarity even though the plate current has stopped. Then the capacitor discharges again, and the magnetic field about the coil is of opposite direction. When the magnetic field again collapses, a new rise of original polarity begins.

Soon afterward, a new burst of plate current is introduced because of the positive swing of the grid waveform, and



(A) Circuit.



(B) Waveforms.

Fig. 7-10. Basic class-C amplifier.

the tank-circuit capacitor is again charged to a maximum negative value, initiating a new cycle of operation. Although the rf amplifier operates class-C and plate current does not occur for the full cycle of the input wave, a good sine wave is developed across the plate tank circuit if the LC constants and load are chosen properly.

In most rf power amplifiers, the class-C bias is developed by the grid current. On the positive peak of the input wave, there is a substantial amount of grid current, which develops a negative charge on grid capacitor C_g (Fig. 7-10A). The current is such that the charge placed on the capacitor biases the tube beyond cutoff. Between the intervals of grid current, the charge leaks off the capacitor through resistor R_g. If time constant R_gC_g is high enough, a reasonably constant bias will be retained during the entire cycle of the input wave. This is equivalent to a dc bias voltage of a value that is several times beyond cutoff. The capacitor is restored to full charge at the crest of each positive input alternation.

207. Define a class-C amplifier.—A class-C amplifier has a grid bias greater than cutoff, causing plate current to be present for only a portion of the positive alternation of the input sine wave. Refer to question 206.

208. What is the function of a grid leak in a class-C amplifier?—In a class-C amplifier, it is the grid current that develops the bias on the grid capacitor. This capacitor in discharging through the grid resistor (grid leak) maintains the tube bias reasonably constant during the full interval of the input cycle. The grid-circuit RC combination acts as a filter and holds the class-C bias constant. The ohmic value of the grid resistor is important in establishing the value of the grid bias and the extent to which it is held constant. The RC combination is a self-adjusting filter and establishes the grid bias in accordance with the level of the input signal, permitting efficient operation of the stage despite the level of the input signal.

209. During what approximate portion of the excitation-voltage cycle is plate current present when a tube is used as a class-C amplifier?—Usually 120-150° of the input cycle corresponding to the most positive portion of the positive alternation of the input wave.

210. A triode transmitting tube, operating with a plate voltage of 1250 volts, has a filament voltage of 10 volts, filament current of 3.25 amperes, and plate current of 150 mA. The amplification factor is 25. What value of control-grid bias must be used for operation as a class-C stage?—The cutoff bias of a triode depends on the plate voltage and μ. In this example, the cutoff bias would be:

$$E_C = \frac{E_B}{\mu} = \frac{1250}{25} = -50 \text{ volts}$$

Inasmuch as a class-C stage is biased at 2, 2.5, 3, etc., times the cutoff value, the actual amount must be considered in determining the eventual class-C bias. For example, if the stage is to be biased at twice the cutoff value, the answer would be:

$$E_{BIAS} = 2(-50) = -100 \text{ volts}$$

211. In a radio-frequency amplifier employing fixed bias, as the plate circuit is varied in adjustment from a point below resonance to a point above resonance, what effect would be observed on the grid current?—As the plate circuit is tuned into resonance, the impedance of the plate circuit rises. On the other side of resonance, the impedance falls. Hence, in tuning through resonance, there will be a slight but discernible peaking of the grid current and a drop away from this value on either side of resonance (Fig. 7-11).

212. In a self-biased radio-frequency amplifier stage having a plate voltage of 1250 volts, a plate current of 50 mA, a grid current of 15 mA, and a grid-leak resistance of 400 ohms, what is the value of the operating grid bias?—Grid bias is determined by the current in the grid-leak resistance. Ohm's law can be used to make the calculation:

$$E_C = I_gR_g = 0.015 \times 4000 = -60 \text{ volts}$$

213. In a series-fed plate circuit of a vacuum-tube amplifier, what would be

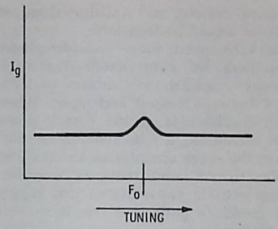


Fig. 7-11. Influence of resonant tuning on grid current.

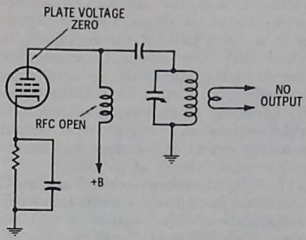


Fig. 7-13. Open rfc in shunt-fed stage.

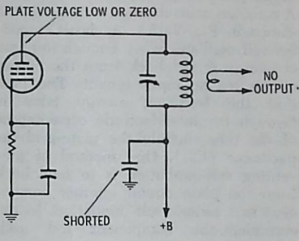


Fig. 7-12. Plate-bypass short with series feed.

the effect of a short circuit of the plate-supply bypass capacitor?—Refer to Fig. 7-12. The short circuit would place a heavy drain on the supply-voltage line and would remove the voltage from the plate of the tube. It could produce an excessive drain on the power supply, resulting in a reduction in the supply-line voltages, and could cause a fuse to blow.

214. In a shunt-fed plate circuit of a vacuum-tube amplifier, what would be the effect of an open circuit in the plate radio-frequency choke?—Such an open circuit (Fig. 7-13) would remove the voltage from the plate of the tube. However, in this case there would be no severe load placed on the supply-voltage line, such as that caused by the shorted capacitor of the previous question.

215. Draw a simple schematic diagram showing a method of link coupling between two radio-frequency amplifier stages.—See Fig. 7-14.

216. What is the advantage of link coupling between radio-frequency amplifier stages?—The major advantage of link coupling is that it blocks the transfer of

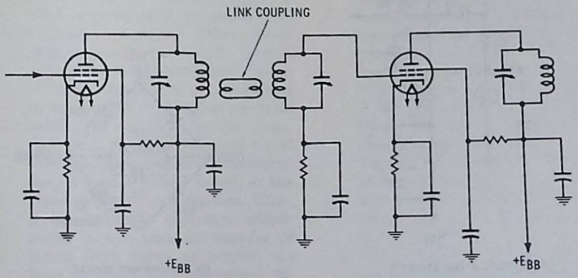


Fig. 7-14. Link coupling between rf amplifiers.

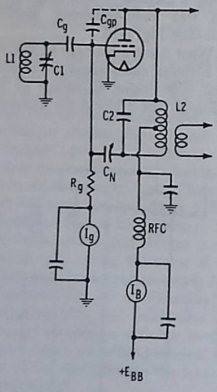
harmonics and other spurious signals between stages. It displays a low-impedance transfer path at the frequency to which the two resonant circuits are tuned. Link coupling also reduces capacity effects and lends itself to the transfer of signal when there is an appreciable separation between the output resonant circuit of one stage and the input resonant circuit of the next.

217. Why are tubes operated as class-C amplifiers not suited for audio-frequency amplification?—The output would be very much distorted. Recall that class-C amplifiers are biased beyond cutoff. Therefore, the plate current is not a copy of the grid-voltage change. It follows, then, that the audio output voltage would also be a very much distorted version of the input signal.

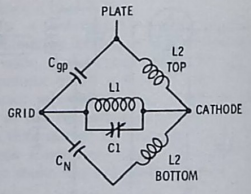
218. Why is it not feasible to employ a vacuum tube operated class-C as an audio amplifier, either singly or in push-pull?—Refer to the previous question. Recall in class-C operation there is output only during a portion of one alternation of the input wave. Even if the tubes were connected in push-pull, only a portion of each alternation would result in plate current, and a distorted output voltage would be inevitable.

219. Why must some radio-frequency amplifiers be neutralized?—Radio-frequency amplifiers are subject to feedback between output and input. When such feedback is of the proper phase and magnitude, a self-oscillation results. Thus the stage operates as an oscillator rather than a radio-frequency amplifier. Interelectrode capacitances can supply the feedback path that results in self-oscillation.

220. Describe how a radio-frequency amplifier stage may be neutralized. What precautions must be observed?—A common neutralization arrangement is shown in Fig. 7-15A. A class-C amplifier self-oscillates when enough in-phase rf energy is fed back from the output circuit to the input circuit. The path that the feedback energy takes is through the interelectrode capacitances of the tube, mainly the plate-grid capacitance (C_{gp}). One method of preventing self-oscillation is to feed back from the plate circuit another component that cancels self-oscillation. In the example, the component fed back



(A) Circuit arrangement.



(B) Equivalent circuit.

Fig. 7-15. Plate neutralization system.

through neutralizing capacitor C_N is of opposite polarity from that fed back to the grid circuit through the interelectrode capacitance. By regulating carefully the size of capacitor C_N, the neutralizing component can be made of equal amplitude and opposite polarity from the component fed back through the tube capacitance.

One can also consider a neutralization system as a balanced bridge (Fig. 7-15B). When the bridge is adjusted properly, the rf currents in the inductive and capacitive legs are balanced. Hence the feedback currents cause no difference in rf potential between grid and cathode.

In the practical neutralization of a stage, some type of indicator must be used. This can be the amplifier grid-current meter or a sensitive output indicator. Types of output indicators are a wavemeter, a pickup loop and series bulb placed near the plate tuned circuit, or a neon bulb.

In setting up for neutralization, the filament power must be turned on, and excitation must be supplied from the preceding stage. However, plate voltage and screen-grid voltage (if a tetrode tube is used) must be turned off. A typical procedure would be:

1. In the neutralization process, the tuning objective is to minimze the net transfer of energy from the plate circuit back to the grid circuit of the stage. In most neutralization systems, a converse plan is used in performing the actual neutralization procedure. The neutralization process is mainly accomplished by minimizing the amount of input signal that is transferred to the output tank when no plate voltage is supplied to the stage. Any such input signal must travel over the same path to the output as output signal would travel to the input without neutralization. Thus, if we make the necessary adjustments to minimize the transfer of signal from input to output, we have in effect also minimized the possibility of the transfer of signal from output to input. Thus, in neutralizing a stage, the normal rf excitation is applied to the grid of the stage to be neutralized.
2. Supply the normal rf signal to the control-grid circuit of the stage. If the stage is being neutralized for the first time, set the neutralizing capacitor to one extreme of its range. Let us assume that it has been set to maximum capacitance.
3. Resonate the grid tuned circuit for maximum rf excitation as indicated by a maximum reading on the dc grid-current meter (I_g in Fig. 7-15).
4. Tune the plate tank capacitor over its range. If the stage is not neutralized, the grid-current meter reading will jump whenever the plate tank circuit is tuned through resonance. Likewise, there will be an indication of output when a sensitive rf indicator is placed close to the plate tank coil.
5. Decrease the capacitance of the neutralizing capacitor slightly. Tune the plate tank circuit through resonance again, and note the kick of the needle. Continue to decrease the setting of the neutralizing capacitor until there is a minimum kick of the needle and a minimum rf output when the plate tank capacitor is tuned through resonance.
6. If the neutralizing capacitance is decreased too far, the rf output and grid kick will increase. There is just one optimum setting for the neutralization capacitor, and it must not insert too little or too much capacitance into the path.
7. The stage is properly neutralized if the plate tank capacitor can be tuned through resonance without changing the grid-current reading. The actual procedure is an attempt to find the setting of the neutralizing capacitor which will give no or very little grid-current meter deflection.
8. Place some load on the output. Apply power to the stage at reduced voltage. Tune the plate tank circuit

for a resonant dip in plate current. Finally, the full plate voltage can be applied, and the plate tank circuit and output coupling are adjusted for optimum operation.

221. Name three instruments which may be used as indicating devices in neutralizing a radio-frequency amplifier stage of a transmitter.—Refer to the previous question. The grid-current meter, neon bulb, and wavemeter or other sensitive output indicator are typical.

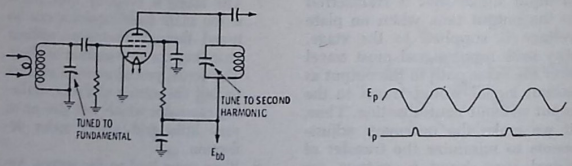
222. Define parasitic oscillation.—Occasionally, oscillators may operate at a frequency other than that of the crystal or the frequency-determining LC circuit. Radio-frequency amplifiers, too, may self-oscillate at some frequency other than that to which they are tuned. Such undesired oscillations are called parasitic oscillations.

223. What is the effect of parasitic oscillations?—Parasitic oscillations are undesired oscillations in an rf amplifier stage. They are self-excited, usually at some frequency quite removed from the desired operating frequency of the amplifier. Usually the presence of parasitics makes it difficult to tune a stage for optimum performance, or the tuning and the operation of the stage seem to be erratic. Meter readings are high or erratic. The stability and efficiency of the stage are harmed, and the presence of such oscillations causes adverse effects when the stage is modulated. Objectionable is the fact that such parasitic oscillations can be radiated and cause an interfering transmission on other than the assigned frequency of the transmitter.

224. Draw a simple schematic diagram of a radio-frequency doubler stage, indicating any pertinent points which will distinguish this circuit as that of a frequency doubler. Describe its operation.—The distinguishing feature of a doubler circuit is that the output resonant frequency is twice the frequency of the input resonant circuit. Refer to Fig. 7-16. Triode or multigrid tubes can be used as doublers and higher-harmonic generators. Triodes and tetrodes can be used as doublers without the necessity for neutralization because the output and input resonant frequencies are different. The beam-power tube is very common because of its low driving power and capability of generating a strong harmonic output.

The harmonic generator is operated class-C. In fact, to obtain a strong harmonic output, the generator is often operated even further beyond cutoff than a normal straight-through class-C amplifier. Efficiency is also a factor in selecting a proper beyond-cutoff bias.

If the harmonic generator is to be operated as a doubler, the plate tank circuit is tuned to twice the frequency of the grid resonant circuit. A burst of plate current is drawn through the plate tank circuit as the grid waveform rises to its positive crest. However, the amount of energy drawn to the plate tank circuit is great enough that the oscillations within the plate tank circuit can go through two cycles before additional energy must be added. Of course, this means that a doubler operates at a lower efficiency than a straight-through amplifier, producing a lower output capability. Note from the waveforms in



(A) Circuit. (B) Waveforms.

Fig. 7-16. Frequency doubler.

Fig. 7-16B that there is a burst of plate current for only every other cycle of the output waveform. Nevertheless, this burst of current shock-excites the output tank circuit into producing a series of oscillations corresponding to its frequency. In fact, as you can note, two cycles are produced before additional energy is added by a burst of plate current. Plate-current bursts occur at a repetition rate corresponding to the input frequency, while the output frequency, as desired, is twice the input frequency.

225. For what purpose is a doubler amplifier used?—Doublers are used when the output signal frequency is to be twice the input frequency.

226. What factors are most important in the operation of a vacuum tube as a frequency doubler?—These factors are output resonant circuit tuned to twice the frequency of the input resonant circuit, proper class-C biasing, adequate grid signal drive, and an output plate resonant circuit that has a high L-to-C ratio which favors the formation of a strong harmonic output wave.

CHAPTER 8

Basic Oscillators, Element 6

SELF-EXCITED OSCILLATORS

227. Draw a simple schematic diagram showing a tuned-grid Armstrong-type triode oscillator with shunt-fed plate. Indicate power-supply polarity.—See Fig. 8-1B.

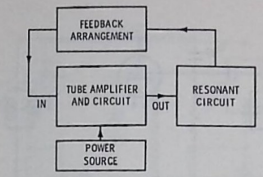
228. Describe how a vacuum tube oscillates in a circuit.—As shown in Fig. 8-1A, an oscillator is an amplifier with a portion of its output fed back to its input. Oscillations occur when this feedback is of the proper amplitude and phase. Because of the 180° phase shift in the common-cathode amplifier, the feedback arrangement must provide an additional 180° phase change to bring the output voltage back in phase with the input variations. This in-phase condition, called positive feedback or regeneration, permits the feedback signal to add to any input change, and self-sustained continuous oscillations can be generated.

In a vacuum-tube rf oscillator, the tube and its associated components (which usually include a resonant circuit) are combined into a feedback-amplifier arrangement capable of making a conversion of dc power to radio-frequency variations. There are many types of oscillators for generating rf energy; all use this fundamental feedback principle. In general, oscillators differ only in the manner in which they obtain the required feedback.

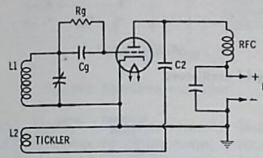
The Armstrong oscillator of Fig. 8-1B is a classic example, and it is used to explain the operation of oscillators in general. In the Armstrong oscillator, the necessary phase reversal of the feedback is determined by the proper connection of grid, cathode, and plate to the resonant-circuit coil and the small tickler coil that feeds back a portion of the plate variations to the control-grid circuit. These fed-back variations are induced in the coil of the grid resonant circuit.

In a vacuum-tube circuit, some tiny voltage or current input variation is inevitable. Such a change is amplified and, in an oscillator arrangement, linked back to the grid circuit through the feedback path from the plate circuit. In the case of the Armstrong oscillator, it is through the small tickler coil. The feedback amplitude, little as it might be initially, will cause an amplified plate-voltage variation which is again fed back to the grid. Hence the original grid-voltage change is reinforced, and an even greater grid-voltage and follow-up plate-voltage change occurs. These variations build up until they are self-supporting and the stage goes into continuous oscillation. Final magnitude of the oscillations is determined by grid limiting and saturation, and by the dc supply voltage and the power capability of the tube.

For the circuit to build up to an oscillating state, the gain of the amplifier



(A) Principle of operation.



(B) Armstrong oscillator.

Fig. 8-1. Oscillator principle and circuit.

must be greater than unity, and in the initial buildup period it must be substantially greater than unit. In the case of the Armstrong oscillator, the magnitude of the feedback is determined by the relative turns ratio between the two coils, L1 and L2, and their proximity. As the buildup continues, the gain of the amplifier falls to the point just a bit greater than unity which overcomes all the circuit losses and sustains continuous oscillation. The polarity of the feedback is determined by the relative winding direction of the two coils, and the connection of the two electrodes to these windings. If the plate in Fig. 8-1 were connected to the top of the tickler winding and the bottom of the tickler winding were grounded, the stage would not oscillate, because the feedback voltage would be out of phase with the control-grid variation, resulting in negative feedback. As the tickler is wired in Fig. 8-1, the feedback is positive, and the voltage induced into the grid resonant circuit from the tickler coil is in phase with the initial control-grid change.

The radio-frequency oscillator is self-biased by the grid current which occurs during the positive alternation of the grid cycle. This grid current charges grid capacitor C_g to a negative level. When the grid current ceases, the charge remains on the capacitor because of the high ohmic value of grid resistor R_g. Time constant R_gC_g is high in comparison to the period of the generated wave.

A power radio-frequency oscillator is usually biased class-C by the grid current. Therefore, the plate current occurs in bursts which shock-excite the resonant circuit. The flywheel energy-storing ability of the resonant circuit causes a sine wave to be developed. Lower-powered oscillators and receiver oscillators are, in general, biased to a lower level than that required for class-C operation.

Capacitor C2 is a blocking capacitor which prevents the dc plate voltage from begin shorted to ground. In some cases its reactance, along with the reactance of the tickler coil, can be used to control the amount of feedback. The radio-frequency choke (rfc) prevents the power supply from placing an ac short on the plate output of the oscillator, and it blocks the radio-frequency energy from the power supply. This particular manner of supplying the dc voltage to the oscillator is known as shunt feed.

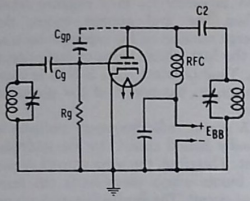
229. Draw a simple schematic diagram showing a tuned-plate, tuned-grid oscillator with shunt-fed plate. Indicate polarity of supply voltages.—See Fig. 8-2A.

230. Draw a simple schematic diagram showing a tuned-plate, tuned-grid oscillator with series-fed plate. Indicate polarity of supply voltages.—Fig. 8-2B.

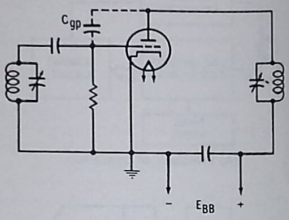
231. Draw a simple schematic diagram showing a Hartley triode oscillator with shunt-fed plate. Indicate power-supply polarity.—See Fig. 8-3.

232. Draw a simple schematic diagram showing a Colpitts triode oscillator with shunt-fed plate. Indicate power-supply polarity.—See Fig. 8-4.

233. What is an electron-coupled oscillator? Explain its principle of operation.—An electron-coupled oscillator (eco), or variable-frequency oscillator (vfo), is shown in Fig. 8-5. Electron-coupled oscillators use pentode or beam-power tubes. The plate circuit serves as a



(A) Shunt fed.



(B) Series fed.

Fig. 8-2. Tuned-plate tuned-grid oscillators.

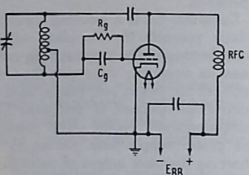


Fig. 8-3. Hartley oscillator.

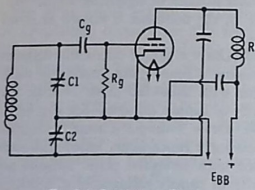


Fig. 8-4. Colpitts oscillator.

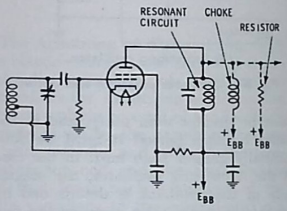


Fig. 8-5. Electron-coupled oscillator.

means of transferring amplified oscillations to a load in a manner that minimizes the influence of the load on the oscillator frequency. The oscillator section itself consists of the cathode, control grid, and screen grid of the multielement tube.

In the operation of the oscillator, the screen grid has the same function as the plate in the oscillators shown previously. In fact, in the circuit of Fig. 8-5, the screen grid, control grid, and cathode are connected into a Hartley oscillator circuit. The oscillations are coupled to the output circuit by way of the electron stream between cathode and plate. The rather loose coupling provided by this arrangement provides high stability and high gain, and the oscillator is much less subject to load variations.

As shown, the plate output circuit can be a resonant circuit, a choke, or a resistor. Although a resonant circuit, when used, can be tuned to the fundamental frequency of the oscillator, it is usually tuned to the second-harmonic frequency. The electron-coupled circuit serves then as both an oscillator and a frequency doubler. When a choke or resistor is used in the plate circuit, the output frequency is the same as the fundamental frequency.

234. Draw a simple schematic diagram of an electron-coupled oscillator, indicating power-supply polarities where necessary.—See Fig. 8-5.

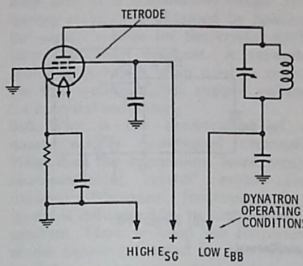


Fig. 8-6. Dynatron oscillator.

235. Draw a simple schematic diagram of a dynatron oscillator using a tetrode. Indicate polarity of power-supply voltages.—See Fig. 8-6.

236. What is a dynatron oscillator? Explain its principle of operation.—In most oscillator circuits, the feedback amplitude and phase are determined by the external resonant circuit and associated components. In the dynatron circuit, the feedback phase, in particular, is determined by the internal characteristics of the tube. When a tube is properly biased for dynatron operation, it is its negative-resistance characteristic that is used to generate the feedback component.

As shown in Fig. 8-6, a dynatron circuit operates with a higher screen-grid voltage than plate voltage. As a result, on a portion of its transfer characteristic there is a dip indicating that the plate current is actually decreasing with an increase in plate voltage. When the plate voltage is lower than the screen-grid voltage, there is a movement of secondary electrons from plate to screen. Such a movement actually decreases the level of the plate current over a portion of the low plate-voltage range. Actually, over this dynatron region, power is being supplied by the plate to the input circuit. This is feedback, and it is of the proper polarity to sustain oscillations.

A resonant circuit is associated with the plate. The shock excitation of this circuit causes the ac plate voltage to vary over the dynatron region. As the plate voltage increases, it increases the electron flow to the plate. However, secondary-emission effects begin, and flow to the screen grid produces a net reduction in plate current. Conversely, a decrease in plate voltage results in a decline in the secondary emission and an actual rise in plate current. The plate circuit is, in effect, generating power that is fed back to support oscillations.

237. What type of oscillator depends upon secondary emission from the anode for its operation?—The dynatron oscillator.

238. Do oscillators operating on adjacent frequencies have a tendency to synchronize oscillations or drift apart in frequencies?—Such oscillators have a tendency to synchronize or lock in on one frequency. The oscillator with the highest resonant Q has the dominating influence.

CRYSTAL OSCILLATORS

239. What crystalline substance is widely used in crystal oscillators?—Quartz.

240. What will be the effect of applying a dc potential to the opposite plane surfaces of a quartz crystal?—The crystal surface will be deformed, though the amount may be slight. The application of an excessive dc voltage can cause the crystal to crack and become damaged permanently.

The application of an appropriate ac voltage will cause the crystal to vibrate, or oscillate, at its resonant frequency. In fact, in so vibrating at its natural frequency, the crystal generates an rf voltage corresponding to this frequency. This is known as the piezoelectric effect.

241. Draw a simple schematic diagram of a crystal-controlled triode vacuum-tube oscillator. Indicate power-supply polarity.—See Fig. 8-7.

It is important to understand the basic operation of a crystal oscillator. Examples of series-fed shunt-fed crystal oscillators are shown in Fig. 8-7. Certain crystalline materials produce voltage when placed under mechanical stress. One such material is quartz, used in the manufacture of transmitting crystals. If

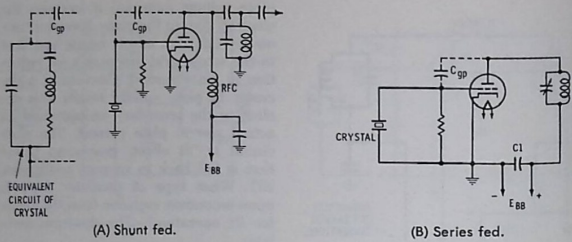


Fig. 8-7. Crystal oscillators.

the pressure on such a crystal is varied and an alternating voltage is applied across the crystal, a vibration is set up. The vibration is at a particular frequency determined by the crystal size and structure. Such a crystal has the characteristics of a resonant circuit. When inserted into an oscillator stage which is tuned to the natural frequency of the crystal, it will vibrate strongly. In fact, a potential difference much like a resonant voltage across a tank circuit is developed across the crystal. This is the variation that is supplied as feedback to the oscillator grid. A similar variation set up in the plate tank circuit is now fed back to the crystal to keep it in mechanical vibration. Inasmuch as the feedback is strongest at the mechanical resonant frequency of the crystal, the frequency of the oscillator is determined by the natural frequency of the crystal. Thus a crystal oscillator is a highly stable oscillator dependent upon the mechanical vibration frequency of the crystal.

As shown in Fig. 8-7A, the crystal is itself a series-resonant circuit having a high inductance and a low capacitance. The capacitance of the crystal and its holder along with the distributed external capacitances shunted across the crystal form an effective parallel resonant circuit. Thus the crystal oscillator is basically a tuned plate, tuned-grid oscillator, the crystal itself forming an equivalent grid resonant circuit. Feedback is by way of interelectrode capacitance C_{gp}, as in the case of the tuned-plate, tuned-grid oscillator. The shunt-fed arrangement requires the appropriate dc blocking capacitor and radio-frequency choke. In the series-fed arrangement, capacitor C1 is the plate-circuit rf bypass.

242. Name four advantages of crystal control over-tuned-circuit oscillators.—The major advantage is high frequency stability. Other advantages are simple circuitry; compact design capability; and high-Q operation much less subject to the influence of external components, external fields, and electrode-voltage changes as compared to the self-excited oscillators.

243. What is the function of a quartz crystal in a radio transmitter?—It determines the stable frequency of operation of the transmitter. It generates the basic radio-frequency wave which will be amplified and multiplied in frequency, if necessary, to form the final transmitted rf signal.

244. Draw a schematic diagram of a Pierce oscillator.—See Fig. 8-8.

245. Why is a separate source of power sometimes desirable for the crystal-oscil-

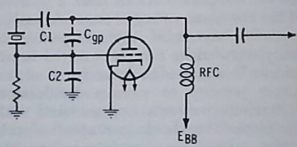


Fig. 8-8. Pierce crystal oscillator.

lator unit of a transmitter?—High frequency stability is obtained by holding the supply voltage for the crystal oscillator absolutely constant. A separate source of power is often used to generate this well-regulated supply voltage for a crystal oscillator.

246. Why is the temperature of a quartz usually maintained constant? What does the expression "low-temperature-coefficient crystal" mean?—The mechanical resonant frequency of a crystal is influenced by its ambient temperature. Thus, to keep the frequency of the signal generated by the crystal oscillator absolutely constant, it is sometimes advisable to keep the temperature of the quartz crystal constant. Crystal ovens are often used for this purpose. A low-temperature-coefficient crystal is one that is cut in such a manner that the temperature has a minimum influence on its resonant frequency. Conversely, a crystal with a high temperature coefficient is one that would have a considerable change in frequency with a change in temperature.

247. What does the statement, "The temperature coefficient of an X-cut crystal is negative," mean?—It means that with an increase in crystal temperature there will be a decrease in frequency of the crystal.

248. What does the statement, "The temperature coefficient of a Y-cut crystal is positive," mean?—This means that an increase in crystal temperature will result in an increase in the resonant frequency of the crystal.

249. Why are the crystals in some oscillators operated at constant temperature?—When the oscillator must be held precisely on a specific frequency, the crystal is often mounted in an oven. In so doing, its temperature is held constant, and the crystal frequency will not drift with changes in the external ambient temperature.

250. Draw a simple schematic diagram of a crystal-controlled vacuum-tube oscillator using a tetrode-type tube. Indicate power-supply polarity where necessary.—See Fig. 8-9.

251. Draw a simple schematic diagram of a pentode-type tube used as a crystal-controlled oscillator, indicating power-supply polarities.—See Fig. 8-10.

252. Name four devices that could be used to indicate oscillation in a crystal oscillator.—A number of such devices are a receiver that is tunable to the crystal frequency, a wavemeter, a neon bulb, a small pilot bulb and loop, a frequency meter, a radio-frequency voltmeter if tunable to the crystal-oscillator range, an oscillator plate or grid meter, and an rf vacuum-tube voltmeter.

253. Draw a simple schematic diagram of a crystal-controlled oscillator and means of coupling to the following radio-frequency amplifier stage, showing power-supply polarities.—See Fig. 8-9.

254. What will be the effect of a high degree of coupling between the plate and grid circuits of a quartz-crystal oscillator?—There will be an increase in the feedback voltage between the plate and the crystal circuit. One must be

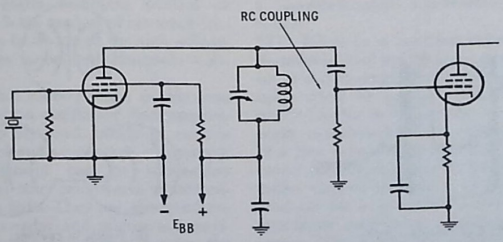


Fig. 8-9. Tetrode crystal oscillator coupled to following stage.

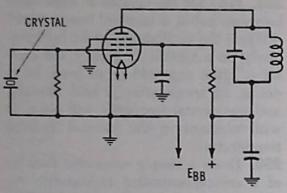


Fig. 8-10. Pentode crystal oscillator.

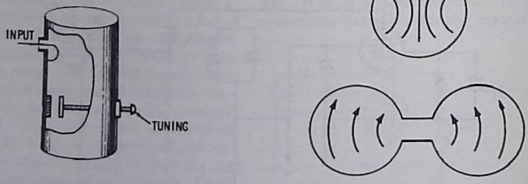
careful not to have excessive feedback, because it can be great enough to shatter and permanently damage the quartz crystal.

255. Why is an additional plate-grid feedback capacitor sometimes necessary in a crystal oscillator?—In order to obtain enough feedback to sustain oscillations when the internal grid-plate capacitance of the tube is insufficient.

256. What cleaning agents may be used to clean the surfaces of a quartz crystal? Is such cleaning ever necessary? Explain.—Whether the crystal surface must be cleaned or not depends upon the quality of its holder and its environment. Grease and dirt can cause erratic operation or no oscillations at all. Carbon tetrachloride and other modern cleaners of similar makeup can be used in crystal cleaning. The crystal is a very fragile device and must be held gently and without permitting fingers or greasy surfaces to touch the critical flat faces of the crystal.

MICROWAVE OSCILLATORS

257. What are cavity resonators and in what type of radio circuits do they find application?—Cavity resonators are a form of resonant circuit used in the uhf and microwave spectra. They are in effect closed-off waveguide segments of various shapes and forms. The simplest resonant cavity can be made by closing off both ends of a half-wavelength section of a rectangular or circular waveguide. In the cavity, there is a circulating magnetic field similar to the circulating radio-frequency current in a conventional resonant circuit. Such a waveguide section can be excited by an inductance loop coming from a coaxial line (Fig. 8-11A). A cavity can be tuned by using either a plunger arrangement or capacitive slugs. These resonant waveguide cavities can be made to have exceptionally high Q and are inherently stable and well shielded. They are used mainly in radar and other microwave equipment and particularly in microwave oscillator circuits using special tubes such as the klystron and magnetron as well as traveling-wave tubes.



(A) Cylindrical cavity. (B) Fields in cavities.

Fig. 8-11. Resonant cavities.

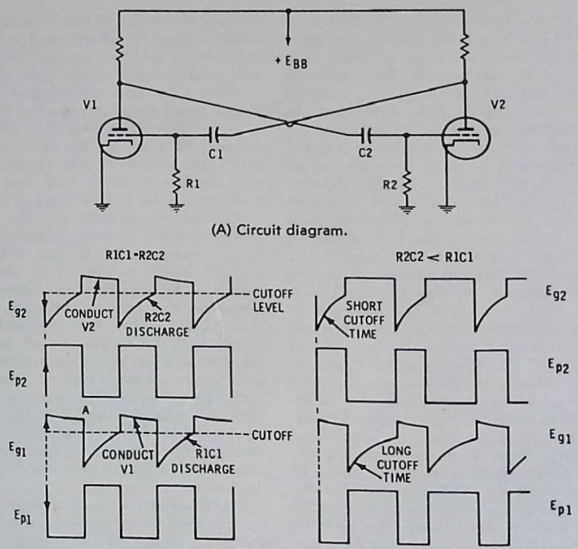


Fig. 8-12. Multivibrator.

258. What determines the operating frequency of a magnetron oscillator? A klystron oscillator?—The principal determinant of frequency in both types of oscillators is the associated resonant cavity. Such a cavity has a very high Q and, therefore, exerts dominant control of frequency. Some control of resonant frequency can be obtained through adjustment of the associated electrode voltages.

259. In what radio circuits do klystron and magnetron oscillators find application?—They are used widely in various types of uhf and microwave equipment. Such equipment can be radio-relay systems and other microwave radiocommunication links. They are also used extensively in radar and microwave navigation gear. In many forms of radar, the klystron serves as the receiver local oscillator while the magnetron is the radar transmitter.

MULTIVIBRATOR RELAXATION OSCILLATORS

260. Draw a simple circuit diagram of a multivibrator oscillator.—See Fig. 8-12A.

261. What is a multivibrator? Explain its principle of operation.—A multivibrator is a two-stage circuit that feeds back upon itself to sustain oscillations. The multivibrator is generally used to generate nonsinusoidal waveforms instead of a sine wave. This is accomplished because the feedback is of high level and either one or the other of the stages is shut off for a specified interval of time, operation switching between the two stages. The principle of operation of a typical multivibrator is as follows.

A multivibrator circuit is shown in Fig. 8-12A. In a multivibrator, one stage is resistance-capacitance coupled (RC coupled) to the second stage, and the second stage, in turn, is RC coupled back to the input of the first stage. In this manner, in-phase feedback can be obtained because the output of the second stage will be in phase with the input to the first stage (two 180° polarity shifts by the tubes). This is a necessary condition for feedback. However, in a multivibrator the feedback is of such a magnitude that the tube conduction is switched on and off alternately by the charges placed on the two grid networks, R1-C1 and R2-C2. Thus the multivibrator does not generate a sine wave, but a squared wave of the type shown in Fig. 8-12B. This type of circuit is called a relaxation oscillator.

In explaining its operation, let us assume that tube V1 is beginning to conduct, and its grid voltage is rising. Consequently, there is a corresponding increase in its plate current and a fall in its plate voltage. This change, in turn, drives the grid of V2 negative and the plate of V2 positive. Since the plate of tube V2 is RC coupled back to V1, there results an amplified increase in V1 grid voltage. The net effect of this feedback activity is to drive the grid of V1 quickly positive to a limiting level and the grid of V2 quickly negative to beyond cutoff. At this point, the feedback activity stops; however, still another change has occurred. The amplified feedback voltage has placed a high negative charge on capacitor C2, and before V2 can conduct again, this charge must leak off through resistor R2. In fact, V2 remains cut off and V1 conducts until the negative voltage being developed across R2 by the declining discharge current falls to the conduction bias of V2. At this moment, the V2 plate current begins to rise, and its plate voltage falls. In turn, the V1 grid voltage swings negative, and its plate voltage swings positive. There results a further increase in V2 grid voltage, and the feedback activity once again takes over. This time, feedback is of opposite polarity with the V1 grid being driven quickly to cutoff and the V2 grid to the limiting level, at which point a further increase in grid voltage will cause no additional increase in the plate current.

Tube V1 is now cut off, and V2 remains conducting, as capacitor C1 discharges through resistor R1. After an interval of time set by time constant R1C1, the grid of V1 once again reaches the conduction level, and the entire cycle of activity begins to repeat.

The waveforms show that the actual period of the generated pulselike waveform corresponds to the sum of the V1 and V2 cutoff periods. Thus the frequency of operation is determined largely by the two time constants, R1C1 and R2C2. If the time constants are equal, both tubes are cut off for the same time interval, and a symmetrical waveform (square wave) is developed in the plate circuit. If a more asymmetrical and pulselike output is desired, it can be obtained by making the two time constants unequal. In so doing, one tube cuts off for a longer time interval than the other.

The frequency of a multivibrator can be increased by decreasing one or both of its time constants. The frequency can be decreased by increasing one or both of the time constants.

262. What determines the fundamental operating frequency of a multivibrator circuit?—The principal frequency-determining elements are the two grid time constants. In the example of Fig. 8-12, these are R1C1 and R2C2.

263. How do multivibrator oscillators differ from Hartley oscillators? In what circuits do multivibrator oscillators find application?—Hartley oscillators are generally used to generate sine waves the frequency of which is determined by a resonant inductor-capacitor combination. Multivibrators generate a nonsinusoidal wave the frequency of which is determined by resistor-capacitor time-constant combinations. Multivibrators are used extensively in test equipment and special waveform-generating circuits. They are used as clocks and timing waveform generators. They also can be found extensively in television and radar units.

CHAPTER 9

Power Sources, Element 6

BATTERIES

264. What is an A battery? B battery? C battery?—The A battery is used for filament power, the B battery for plate and screen-grid power, and the C battery for grid bias.

265. What material is used in the electrodes of a common dry cell?—In the most common type of dry cell (Fig. 9-1), the positive electrode is carbon, and the negative electrode is zinc.

266. How may a dry cell be tested to determine its condition?—A dry cell is best tested with a voltmeter while it is under load.

267. How can the condition of charge of dry B batteries be determined?—They are also tested under load by measuring their terminal voltages.

268. What is polarization as applied to a primary cell, and how may its effect be counteracted?—Polarization refers to the hydrogen-gas accumulation at the positive electrode. Maganese dioxide serves as a depolarizer and counteracts the polarization which can increase the effective internal resistance of the battery.

269. What precaution should be observed in storing spare B batteries?—Battery deterioration is slowed down by storage in dry and reasonably cool places.

270. Show by a diagram how to connect battery cells in series.—See Fig. 9-2. The series connection of like cells increases the net voltage, while the current capability remains about the same as that for a single cell.

271. Show by a diagram how to connect battery cells in parallel.—See Fig. 9-3. Parallel connection increases the current capability while the voltage remains the same as that of a single cell.

272. How does a primary cell differ from a secondary cell?—A secondary cell is rechargeable, whereas a primary cell is not.

273. Draw a sketch showing the construction of a storage cell.—The basic construction of a lead-acid storage cell is shown in Fig. 9-4.

274. What is the chemical composition of the active material composing the negative plate of a lead-acid storage cell? The positive plate?—The negative plate is constructed of spongy lead. The positive plate is lead peroxide.

275. Describe an electrolyte.—The electrolyte is a liquid or paste that forms a conducting path between the two electrodes of a battery. Current is the result of a motion of ions, and the actual electrolyte decomposes when a load is placed on the battery.

276. What is the meaning of electrolyte? List two types of radio equipment in which it may be used.—Refer to the previous question. In the case of many primary cells, the electrolyte is a paste. In the case of a storage, or secondary,

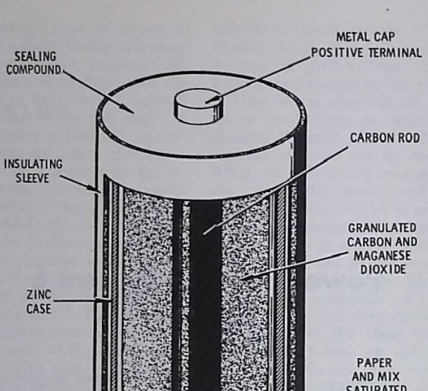


Fig. 9-1. Construction of a carbon-zinc cell.

cell, the electrolyte is more often a liquid. This liquid, too, decomposes with battery drain. However, the secondary battery may be recharged and the electrolyte restored to its original condition.

277. **What is the chemical composition of the electrolyte of a lead-acid storage cell?**—It is a solution of sulphuric acid and distilled water having a specific gravity of approximately 1.26 to 1.275. (Specific gravity is the weight of the solution compared to that of an equal volume of pure water.)

In a secondary (storage) cell, the battery can be discharged and recharged many times (Fig. 9-5). The chemical reactions are reversible; therefore, the battery is recharged by applying a reverse current. This in turn restores the electrolyte to the original fully charged battery condition. On discharge the sulphuric acid is removed from the water, and on charge it is restored to the water.

When a load is placed on a charged battery (Fig. 9-5A), a chemical reaction takes place between the lead compounds of the electrode and the electrolyte. Since the electrolyte is sulphuric acid, the separation (dissociation) of the solution results in positive hydrogen ions (H) and negative sulfate ions (SO_4). The chemical reaction at the positive plate changes the lead peroxide to lead sulfate. At the negative plate, a conversion is made between sponge lead and lead sulfate. In effect, the sulphuric acid is being removed from the solution, and lead sulfate is being formed on the electrodes. At the negative electrode, the chemical reaction frees electrons which move through the external circuit. When the cell is discharged (Fig. 9-5B), the electrolyte is composed of a minimum amount of sulphuric acid and a maximum amount of water.

In charging the cell (Fig. 9-5C), a dc current of opposite direction is passed through the cell. Charge motion reverses, the lead-sulfate coating is broken off, and the sulfate ions are returned to the electrolyte. After a suitable charging interval, the electrolyte is restored to a

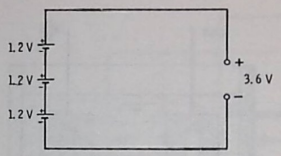


Fig. 9-2. Cells connected in series.

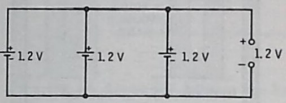


Fig. 9-3. Cells connected in parallel.

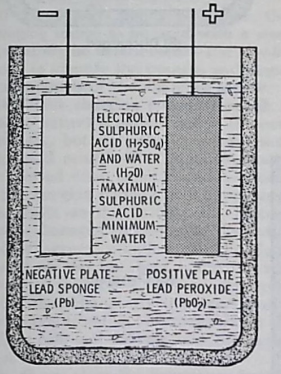


Fig. 9-4. Basic makeup of charged lead-acid cell.

condition of maximum sulphuric acid.

278. What is the approximate fully charged voltage of a lead-acid cell?—The fully charged voltage of an individual cell is 2.1 volts. Thus the fully charged voltage of a so-called 6-volt storage battery is 6.3 volts; for a 12-volt storage battery, it is 12.6 volts.

279. Define specific gravity as used in reference to storage batteries.—Specific gravity in relation to storage cells refers to the weight of the electrolyte solution compared to that of an equal volume of pure water.

280. What method of connection should be used to obtain the maximum short-circuit current from a group of similar cells in a storage battery?—The current capability is increased by connecting the cells in parallel.

281. What method of connection should be used to obtain the maximum no-load output voltage from a group of similar cells in a storage battery?—The net voltage is increased by connecting the cells in series.

282. A 6-volt storage battery has an internal resistance of 0.01 ohm. What will be the current when a three-watt, 6-volt lamp is connected?—The lamp resistance is:

$$R_L = \frac{E^2}{P} = \frac{6^2}{3} = 12 \text{ ohms}$$

Current is:

$$I = \frac{E}{R_L + R_{int}}$$

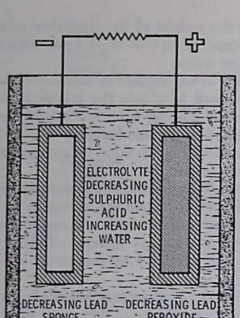
$$= \frac{6}{12 + 0.01} = 0.4996 \text{ ampere}$$

283. Why is low internal resistance desirable in a storage cell?—Power capability and voltage are lost as a result of a high internal resistance. The battery voltage under load drops, and the current-delivering ability of the battery is limited.

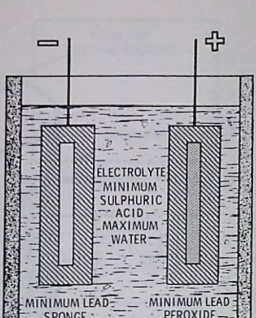
284. What is the cause of the heat developed within a storage cell during charge or discharge?—Heat is a byproduct of the chemical activity as well as the heat generated when charges move through a resistance.

285. What form of energy is stored in lead-acid storage batteries?—The energy stored is chemical energy. The connection of an external load sets off a chemical reaction that produces motion of electric charges.

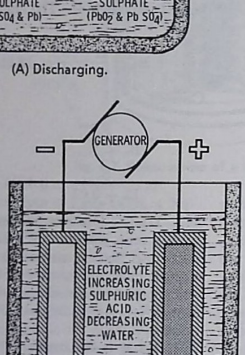
286. Draw a diagram of the charging circuits of two batteries using a four-pole, double-throw switch so that while one battery is on charge, the other is on discharge. Indicate the dc power source, voltage-dropping resistors, and connec-



(A) Discharging.



(B) Discharged.



(C) Charging.

Fig. 9-5. Battery chemical reactions.

tions to the battery load.—See Fig. 9-6. The purpose of the four-pole, double-throw switch is to transfer the load from one battery to the other as the charging source is switched in a converse manner. In this arrangement, the charging voltage is always being applied to the battery that is not supplying power to the load. The purpose of the charging resistor is to limit the charging current to a satisfactory and safe value. Batteries can be charged very quickly using a fast

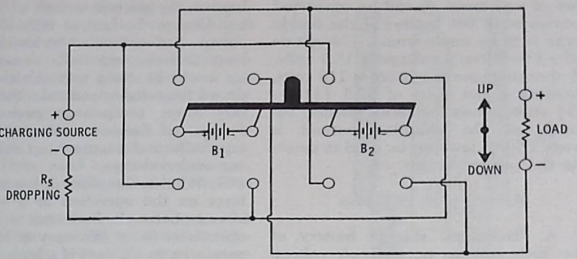


Fig. 9-6. Circuit for charging one battery while second battery supplies load.

charging rate. However, battery life is extended by using a longer charge time and a lower charge current.

287. How may the polarity of the charging source to be used with a storage battery be determined?—Use a voltmeter to identify the positive and negative terminals of the charging source.

288. If the charging current through a storage battery is maintained at the normal rate, but its polarity is reversed, what will result?—This practice should be avoided when using a lead-acid cell. If the charging source places a high current drain on the battery, the battery can be damaged by the rapid discharge and/or severe sulfation. If the load placed on the lead-acid battery is not severe, it will cause battery discharge rather than charge. An improper source connection is not as objectionable for an Edison cell, and damage may not occur or it may be only minimal.

289. If you place the emergency batteries on charge and the overload circuit breakers refuse to stay closed, what is the trouble?—It may indicate an improper load placed on the source by a reverse-polarity connection, or it could be a defective battery or cell placing a low-resistance path across the charging source.

290. Why does the charging rate to a storage cell being charged from a fixed-voltage source decrease as charging progresses?—This is normal because the voltage of the storage cell rises as the cell is charged. Its polarity opposes the voltage of the source, and there is a decline in charging current.

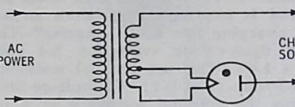


Fig. 9-7. Tungar charger.

291. Describe the construction and operation of rectifier tubes that are used for charging batteries. Draw a diagram of a battery-charging circuit employing such a tube.—See Fig. 9-7. The rectifier tube must have a high current capability and usually is a gas-filled type called a tungar bulb. The transformer, too, is rather special because of the high filament current and charging current it must supply. The rectifier circuit itself can be very simple, the major difference being the special transformer and high-current tube that must be used to supply the high charging current. In recent years, solid-state chargers have become increasingly popular.

The tungar filament is capable of high current emission. The emitted electrons moving from cathode to plate bombard the gas atoms, freeing ions that reduce the resistance of the current path between cathode and anode and greatly increasing the current-carrying capability of the tube.

292. A storage battery with a terminal voltage of 12.5 volts is to be trickle charged at a 0.5-ampere rate. What

value of resistance should be connected in series with the battery if the trickle charge is to be made from a 110-volt dc line?—The battery voltage is 12.5 volts, and charging-source voltage is 110 volts, indicating a net drop of 97.5 (110 — 12.5) volts across the series resistor. Inasmuch as the charging current is known, Ohm's law can be used to determine the resistor value:

$$R_s = \frac{97.5}{0.5} = 195 \text{ ohms}$$

293. A discharged storage battery of three cells has an open-circuit voltage of 1.8 volts per cell and an internal resistance of 0.1 ohm per cell. What potential is necessary to produce an initial charging rate of 10 amperes?—The total open-circuit voltage is 5.4 volts (3×1.8). The net internal resistance is 0.3 ohm (3×0.1). The voltage drop across the internal resistance as a result of 10 amperes of charging current is 3 volts (10×0.3). To overcome this internal voltage drop, it is necessary that the charging voltage be that number of volts higher than the net voltage of the battery, or 8.4 volts ($3 + 5.4$).

294. When should distilled water be added to a lead-acid storage cell and for what purpose?—The battery water level declines as a result of heat and evaporation. This does not happen to the sulphuric acid. Therefore, to obtain the optimum specific gravity and to make full use of the total plate area in an efficient manner, maintain the liquid level according to the battery maintenance directions. This is accomplished by an occasional addition of distilled water to the electrolyte. For most lead-acid cells, the liquid electrolyte level is usually some recommended fractional part of an inch above the top of the plates. A common figure is ¼ inch.

295. Describe the care which should be given a group of storage cells to maintain them in good operating condition.—There are various maintenance considerations. Three factors of principal concern are: keep the electrolyte up to level, avoid undercharge and/or excessive discharge, and maintain cleanliness and proper ventilation. Watch can be kept on the electrolyte with a hydrometer. Charge the battery fully after discharge, and maintain a trickle charge to keep batteries, especially unused ones, up to charge. Keep terminals clean and connections tight, and take the necessary steps to prevent oversulfation. Sparks and flames are always a hazard, especially near a battery just charged or one under charge.

296. What is the effect of low temperatures on the operation of a lead-acid storage battery?—Batteries, in general, operate at lower efficiency at low temperatures. In the case of a lead-acid cell, this would mean a reduction in its ampere-hour capacity.

297. What special precautions should be taken when lead-acid storage cells are subject to low temperatures?—Try to keep the battery up to full capacity with cells fully charged.

298. Why should the tops of lead-acid storage batteries be kept clean and free from moisture?—This form of maintenance counteracts terminal corrosion and the placing of a discharge path across the terminals.

299. What steps may be taken to prevent corrosion of the terminals of lead-acid storage cells?—Keep the terminals clean and terminal connections tight. A coating of petroleum jelly or more modern preparations offers corrosion protection.

300. Why should adequate ventilation be provided in the room housing a large number of storage cells?—During the charging process, lead-acid storage cells emit hydrogen gas, which is both flammable and explosive. This hazard is made less severe with proper ventilation.

301. What should be done if the electrolyte in the lead-acid storage cell becomes low due to evaporation?—Add distilled water to the prescribed level. Usually there is no loss of sulphuric acid. However, the specific gravity should be checked at full charge to make certain that the proper relative amounts of sulphuric acid and distilled water are maintained.

302. Why should care be taken in the selection of water to be added to a stor-

age cell to replace that lost by evaporation?—Certain impurities can result in local-action deterioration of battery cells. Local action refers to the formation on the battery plates of a hard sulfate which cannot be removed by the normal charging activity.

303. What chemical may be used to neutralize a storage-cell acid electrolyte?—Three good agents are ammonia, bicarbonate of soda, and sodium carbonate.

304. How may the state of charge of a lead-acid storage cell be determined?—A hydrometer (Fig. 9-8) gives a measure of the relative levels of water and sulphuric acid. Normal readings for a lead-acid cell are 1.3 fully charged and 1.1 discharged.

305. What are the effects of sulfation?—Sulfation is the accumulation on electrodes of hard lead sulfate that cannot be broken down by recharging. Severe sulfation makes the battery useless; limited sulfation reduces its capacity (ampere-hours), and it must be recharged more often.

306. What may cause sulfation of a lead-acid storage cell?—Causes are frequent undercharging, too high a specific gravity, leakage or internal defects, and standing idle in a discharged condition.

307. If a hydrometer is not available, how can the condition of charge of a storage battery be determined?—A reasonable indication of proper charge is a normal terminal-voltage reading under substantial load.

308. What is indicated if in testing a storage battery the voltage polarity of some cells in the battery is found reversed?—A reverse charge is indicated.

309. What is the effect of local action in a lead-acid storage cell, and how may it be compensated?—Local action is undesired electrolysis within the battery as a result of impurities in the electrode material or supporting structures of the battery. Electrolysis occurs even though there is no load or no recharging of the battery. The deteriorating effects of local action can be minimized by supplying a light but continuous charging current (trickle charge) to the battery when it is not in use.

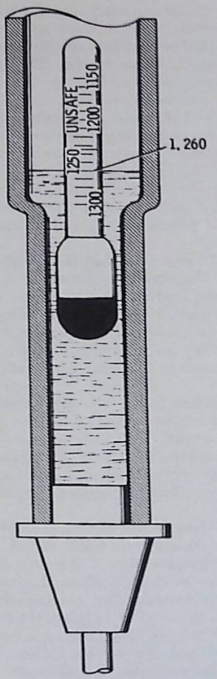


Fig. 9-8. Normal hydrometer reading.

310. Lacking a hydrometer, how may you determine the state of charge of a storage battery?—Refer to question 307.

311. Your emergency lead-acid storage battery has a specific gravity of 1.12. What should be done?—Make certain the electrolyte is at the proper level, and place the battery on charge.

312. What may cause the plates of a lead-acid storage cell to buckle?—Too high a charging current over too long an interval, or a high discharge current that continues after the specific gravity has dropped below the safe value.

313. If an auxiliary storage battery has a voltage of 12.4 volts on open circuit and 12.2 volts when the charging switch is closed, what is the difficulty?—The voltages indicate that the charging polarity has been reversed.

314. What could cause abnormally low voltage at the input power terminals of a lifeboat radiotelegraph transmitter while it is in operation?—The cause could be a defective or improperly charged battery or a transmitter defect that is placing too great a load on the battery.

315. If you find that it is impossible to keep the receiver storage A battery charged and at the same time maintain the required watch, what remedy may be found?—If no replacement battery is available, an emergency step would be to increase the charging rate of the battery.

316. What is the chemical composition of the active material in the negative plate of an Edison-type storage cell? The positive plate?—The negative plate is composed of iron and iron oxide. The positive plate is composed of nickel oxide.

317. What is the chemical composition of the electrolyte used in an Edison-type storage cell?—A solution of potassium hydroxide, lithium hydrate, and distilled water. The electrolyte has a specific gravity of approximately 1.2.

318. What is the approximate fully charged voltage of an Edison storage cell?—Approximately 1.37 volts.

319. What are the main differences between Edison and lead-acid storage batteries?—The major difference is the composition of the electrodes and electrolyte. Refer to questions 274 through 277, 316, and 317. The voltage and specific gravity differ a limited amount. As compared to a lead-acid battery, the Edison cell has lower current capability but is less subject to damage and has a less corrosive electrolyte.

320. How may the condition of charge of an Edison cell best be determined?—The condition of charge can be determined by monitoring the terminal voltage under load or by using a special ampere-hour meter. The specific gravity of the electrolyte changes but slightly with charge and discharge, and its measurement is not practical as a monitoring gauge. Precise checks of battery condition can be obtained by making a comparison with the discharge standard for the particular Edison battery.

321. Describe three causes of a decrease in capacity of an Edison-type storage cell.—Deterioration of the electrolyte, improper charging schedule, or overheating and impurities in the electrolyte or plates.

322. Why should an Edison storage battery not be charged at less than the normal rate specified by the manufacturer? Explain.—A charging rate less than that recommended results in a lower charge capacity than normal. Chemical reactions are hampered by a low charging rate.

TUBE RECTIFIERS AND FILTERS

323. Draw a simple schematic diagram of a rectifier and filter for supplying plate voltage to a radio-receiver.—See Fig. 9-9. The rectifier tube converts the ac variations across the transformer sec-

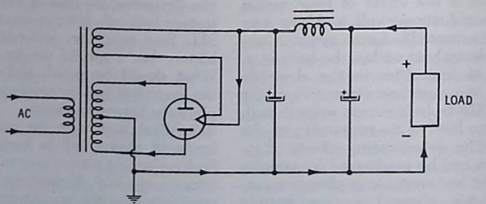


Fig. 9-9. Rectifier and filter combination.

ondary into unidirectional output pulses. When the transformer secondary is positive at the top, the electron flow is from ground through the load, to the cathode of the rectifier tube, to the top plate, and then to the top of the transformer secondary. Notice that the electron flow through the load is toward the positive dc potential.

When the voltage across the transformer secondary is on its negative excursion, the bottom of the secondary is positive with respect to the center tap, and the bottom rectifier conducts. The electron flow is again from the center tap, through the load to the cathode of the rectifier tube, to the bottom plate of the tube, and then to the bottom of the transformer secondary. Notice that current passes through the load in the same direction as on the first alternation. A unidirectional current has been established.

The rectifier voltage is in pulsations. Consequently, there is an ac voltage variation called a ripple component. If no filter circuit were used, a rather high-amplitude ac voltage would be impressed upon the dc voltage at the power-supply output. The function of the filter network is to reduce this ac ripple.

A filter network is composed of shunt capacitors and series inductor(s). The basic characteristic of a capacitor is to oppose a voltage change. Thus ripple-voltage variations are smoothed out by the filter capacitor. An inductor opposes a change of current. Hence current variations that would ordinarily reach the output and build up a ripple voltage are smoothed out by the filter choke. A combination of capacitors and choke can reduce ripple variation to a very small percentage of the original. The LC network, in effect, acts as a low-pass filter with a high attenuation for the usual 60-Hz or 120-Hz ripple frequency at the rectifier output. The ripple frequency is 120 Hz for the full-wave rectifier of Fig. 9-9. When a half-wave rectifier is used, the ripple frequency is 60 Hz.

324. List the main advantages of a full-wave rectifier as compared to a half-wave rectifier.—The principal advantages are lower ripple and higher current capability with less costly components. A full-wave rectifier requires smaller filter components because of the higher ripple frequency (refer to previous question), and it has the capability for a higher dc output current. There is no current for a complete half-cycle in the half-wave rectifier (Fig. 9-10A); therefore, its output voltage regulation is poor.

325. What are the primary advantages of a high-vacuum rectifier as compared to the hot-cathode mercury-vapor rectifier?—The advantages are a higher peak inverse voltage and less critical operating temperature. The cathode of the mercury-vapor tube must always be brought up to operating temperature before the anode voltage can be applied safely. This precaution is usually taken only for the higher-powered high-vacuum rectifier tubes. The gas ionization process in the mercury-vapor tube also generates rf interference (hash), which is not a problem with a high-vacuum rectifier. Moreover, the low peak inverse voltage and the output transients of a gas-filled rectifier preclude the use of a capacitor-input filter.

326. What are the advantages of the high-vacuum rectifier tube as compared to the hot-cathode gas-filled tube?—Refer to the previous question.

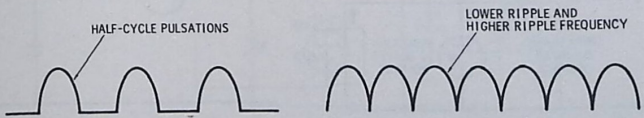


Fig. 9-10. Output waveforms of rectifiers.

327. Compare the advantages and disadvantages of high-vacuum and hot-cathode mercury-vapor rectifier tubes.—Refer to question 325 for the advantages of high-vacuum tubes as rectifiers. The advantages of a mercury-vapor rectifier are the low fixed internal voltage drop, which improves voltage regulation; high current capability; lower filament power; and low anode dissipation.

328. What are the principles of a gas-filled rectifier tube?—The gas in the tube ionizes when the applied voltage exceeds its firing potential. The low-resistance conducting path presented by the ionized gas permits passage of a high current with a low internal voltage drop. Hence, over the operating current range of gas-filled tubes, good regulation and a low internal voltage drop are sustained. Gas-filled rectifier tubes are common for developing dc power for the plate circuits of higher-powered transmitting tubes. They afford a low-cost and practical means of meeting these high power requirements.

329. What action makes possible the high conduction currents of a hot-cathode, gas-filled rectifier tube?—It is the ionization of the gas within the tube which presents a low-resistance path for the movement of electrons between cathode and anode. Therefore, the tube has a very high current capability and is able to meet the power demands of heavy loads.

330. Why should the filament or heater in a mercury-vapor rectifier tube reach normal operating temperature before the plate voltage is applied?—The emitting surface should be brought up to operating temperature before a power demand is made. This precaution prevents damage to the cathode emitting surface and permits proper ionization of the gas whenever a power demand is made.

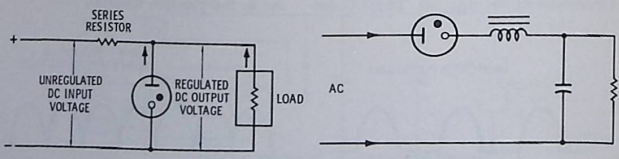
331. Why are small resistors sometimes placed in series with each plate lead of mercury-vapor rectifier tubes connected in parallel?—This precaution permits proper ionization of both tubes and prevents an uneven division of load between the paralleled tubes.

332. Explain the principle of operation of a cold-cathode gaseous rectifier diode.—As the name "cold cathode" suggests, no filament power is required to heat the cathode. The gas within the tube ionizes when the anode voltage is applied, providing a low-resistance conduction path between cathode and anode. The positive ions strike the cathode with sufficient momentum to cause heating and secondary emission. These electrons, too, move to the anode.

The cathode is coated with a material that provides efficient electron emission. The anode is small, and its rod-like construction attracts these electrons. As in a conventional rectifier tube, no current can be conducted when the anode is more negative than the cathode.

333. Discuss the uses of copper-oxide rectifiers.—The copper-oxide rectifier is a metallic rectifier. It is a small low-current, low-voltage rectifier principally used in ac meters. It has a long life and constant characteristics and can be made economically. Its small size and constant performance make it ideal for use in test instruments.

334. Draw a simple schematic diagram of a cold-cathode electron tube connected as a voltage regulator. As a rectifier.—See Fig. 9-11.



(A) Voltage regulator. (B) Rectifier.

Fig. 9-11. Circuits employing cold-cathode tubes.

335. What is the ratio of the frequencies in the output and input circuits of a single-phase, full-wave rectifier?—The ratio of output ripple frequency to ac power input frequency is two to one. If the rectifier is being powered from a 60-hertz source, the output ripple frequency will be 120 hertz.

336. What factors determine the ratio of the primary and secondary currents in a power transformer?—This ratio is related inversely to the turns ratio, or:

$$\frac{I_S}{I_P} = \frac{N_P}{N_S}$$

337. What factors determine the no-load voltage ratio of a power transformer?—The ratio of the voltages varies directly with the turns ratio, or:

$$\frac{E_S}{E_P} = \frac{N_S}{N_P}$$

338. What is the secondary voltage of a transformer which has a primary voltage of 100 volts, 200 primary turns, and 40 secondary turns?—The voltage ratio varies directly with the turns ratio, or:

$$\frac{E_S}{E_P} = \frac{N_S}{N_P}$$

$$E_S = E_P\left(\frac{N_S}{N_P}\right) = 100 \times \frac{40}{200} = 20 \text{ volts}$$

339. What factors determine the efficiency of a power transformer?—A considerable number of factors, including the type of external load and its power factor, influence the operating efficiency of a transformer. However, the three major factors related to transformer efficiency stem from the losses contributed by eddy currents, hysteresis, and I^2R losses. Refer to question 33.

340. What is the maximum allowable total secondary voltage of a center-tapped transformer to be used in a full-wave rectifier circuit in connection with rectifier tubes having a peak inverse voltage rating of 10,000 volts.—If the peak inverse voltage rating of the rectifier tubes is 10,000 volts, the maximum permissible total secondary voltage is limited to a value of 7,070 volts rms.

The full-wave arrangement of Fig. 9-12 shows how a high negative inverse voltage is supplied to rectifier V1 when rectifier V2 is conducting. In the example, it has been assumed that 1000 volts rms (one-half of the total secondary voltage) appears across each half of the secondary. This corresponds to a peak amplitude of 1414 volts. On the peak of the negative alternation of the secondary sine wave, this amount of negative voltage is being applied to the anode of V1. At the same time, V2 is conducting; therefore, approximately the same voltage as at the anode of V2, except for the small voltage drop across the conducting diode, appears at the input of the filter. Thus approximately 1414 volts positive is applied to the cathode of the top diode. The net voltage drop between anode and cathode is twice this value, or

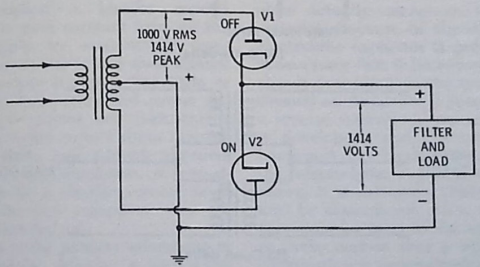


Fig. 9-12. Peak inverse voltage across nonconducting tube of a full-wave rectifier.

2828 volts (minus the small voltage drop across V2). This corresponds to twice the peak amplitude of the voltage that appears across one half of the secondary.

341. If part of the secondary winding of the power-supply transformer were actually shorted, what would be the immediate effect?—The effect would depend on the number of shorted turns and the type of transformer winding, as well as the load placed on the transformer output. A serious short may result in an increase in the primary current and a blown fuse and/or overheating of the transformer.

342. Why is a capacitor sometimes placed in series with the primary of a power transformer?—For power-factor correction.

343. What would happen if a transformer designed for operation on 60-hertz voltage were connected to a 120-hertz source of voltage?—This would not be injurious to the transformer. In fact, the primary impedance would now be higher, and the primary current would be more limited.

344. What would happen if a transformer designed for operation on 500 hertz were connected to a 60-hertz source of the same voltage?—This would be injurious to the transformer. Now the impedance is very much below the normal value, and there would be an excessive primary current, overheating, and possibly burnout.

345. Why should the metallic case of a high-voltage transformer be grounded?—This is a very important safety connection. It minimizes the possibility of danger to personnel because of possible transformer shorts to the case or a buildup of high-voltage static charges.

346. Draw a diagram showing how three power transformers can be connected for operation on a three-phase circuit. Show how only two transformers can be connected for full operation on a three-phase circuit.—See Fig. 9-13.

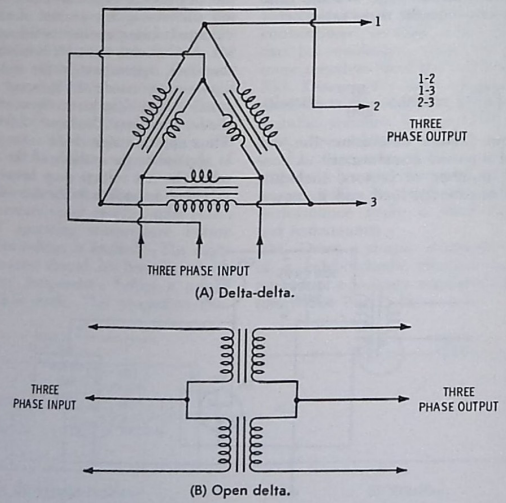


Fig. 9-13. Three-phase transformer connections.

347. Draw a simple circuit diagram of a voltage-doubling power supply using two half-wave rectifiers.—See Fig. 9-14.

348. What is the principal function of the filter in a power supply?—The filter removes the amplitude variations (ripple) from the pulsating dc output of the rectifier.

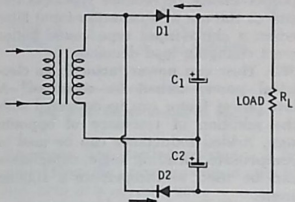


Fig. 9-14. Voltage-doubler circuit.

349. What are the relative advantages of capacitor-input and choke-input filters when used with rectifiers?—The capacitor-input filter permits a higher dc load voltage but at a sacrifice in voltage regulation. The peak voltage across the input filter capacitor is higher than that of the first capacitor of a choke-input filter. Conversely, a choke-input filter is used when voltage regulation is a primary concern. The choke-input filter is particularly effective in maintaining more constant output voltage under changing load conditions.

350. Why are bleeder resistors used in power supplies?—A bleeder resistor maintains a more constant load on the power supply by maintaining some power drain on the supply even though the load proper is demanding little or no current. It is connected across the power-supply output and maintains a specific minimum current drain through the filter choke and thereby improves the power-supply regulation. A secondary benefit of a bleeder resistor is to discharge the filter capacitors when the power is switched off.

351. What is the primary advantage to be obtained by shunting a high-resistance, fixed resistor across each unit of a high-voltage series capacitive bank in the power-supply filter circuit of a transmitter?—These resistors distribute the voltage uniformly among the capacitors of the series bank. The division of the dc voltages on the capacitors is a function of the individual internal resistances of those capacitors. If these resistances are unlike, one or more capacitors may be required to support a higher than normal dc voltage. External resistors ensure a uniform distribution of the dc voltages.

352. Indicate the approximate values of power-supply filter inductances encountered in practice.—Typical values vary between 5 and 20 henrys; some are a bit higher.

353. What is the purpose of an air gap in the core of a filter choke coil?—The air gap prevents core saturation and aids the attainment of high-inductance and high-current capability.

354. What is the effect of loose laminations in a filter choke?—Chokes and transformers have a tendency to chatter when their laminations are loose.

355. Explain the principle of operation of an electrolytic capacitor. What precaution should be observed when connecting electrolytic capacitors in series?—An electrolytic capacitor differs in its construction from other fixed types in that its oxide-coated foil plate is immersed in a wet or dry electrolyte. This electrolyte also serves as the negative plate, with its external connection made by way of another metal foil. The oxidized film that forms on the positive plate actually serves as the dielectric material. Because of the electrolyte, an electrolytic capacitor is polarized, and it is necessary that it be connected into the circuit according to the polarization indicated on its cover. If it is connected in a reverse manner, a low-resistance path is developed, and the capacitor overheats and may be destroyed. In connecting electrolytic capacitors in a series string, it is necessary that this polarization be maintained. Also, external resistors must be used in the series sequence to make certain that a uniform voltage distribution is maintained among the capacitors of the series chain.

356. How may a filter capacitor be checked for leakage?—A capacitor meter that permits the application of a dc voltage to the capacitor is the best means of checking the condition of the capacitor. A series-connected source of voltage, milliammeter, and capacitor under test can be used to obtain an actual leakage-current measurement, which can be compared with the specifications of the particular capacitor.

357. Why is it desirable to have a low-resistance filter choke?—A low-resistance choke improves the voltage regulation. The load current in passing through the resistance of the choke develops a voltage drop across the choke that subtracts from the available dc output voltage. A greater current demand made by the load results in a greater voltage drop across the choke resistance and a lower voltage available across the load.

358. What is a desirable feature of an electrolytic capacitor as compared to other types?—A capacitor of large capacitance and reasonably high breakdown voltage can be housed in a small case.

359. When filter capacitors are connected in series, resistors of high value are often connected across the terminals of the individual capacitors. What is the purpose of this arrangement?—A uniform distribution of voltages, permitting each capacitor to be placed under the same stress. Refer to question 351.

360. What method is used to obtain more than one value of voltage from a fixed-voltage dc source?—Two or more resistors can be connected in series to obtain intermediate values of voltage lower than the actual dc source voltage. Those values can be obtained by selecting the proper relative resistances that make up the series group.

361. Define voltage regulation.—Voltage regulation is the ratio of the change in output voltage between no load and full load to the full-load voltage, or:

$$\% \text{ Regulation} = \frac{E_{NO} - E_{FULL}}{E_{FULL}} \times 100$$

362. What is meant by regulation of a power supply? What causes poor regulation?—Refer to the previous question. In this case, the symbol E in the equation refers to the dc output voltage of the power supply. Poor regulation (change in output voltage with change in load) can be caused by an inadequate filter, an inefficient transformer, or a high-resistance choke. Also, poor regulation could result from an improper choice of rectifier type and circuit or the use of a capacitor-input filter when a choke-input type would better meet changing load demands.

363. How can power factor in an electrical power circuit be corrected?—A low power factor can be corrected with the addition of reactance of opposite sign. Added inductance can be used to compensate a leading angle; capacitance can be used to compensate a lagging angle.

364. What load conditions must be satisfied in order to obtain the maximum possible power output from any power source?—There is always maximum transfer of power when the impedance of the load is made to match the impedance of the source. (This assumes the impedances are resistive. If the impedances include reactive components, there is an additional requirement for maximum power transfer: The reactance of the load must be equal to the reactance of the source but of opposite sign. The resistive components must be equal.)

MOTORS AND GENERATORS

365. Describe the action and list the main characteristics of a shunt-wound dc motor.—In a shunt-wound dc motor (Fig. 9-15), the field winding and its speed control are in parallel with the armature. It is customary to apply maximum field current when starting a shunt motor, but the armature current is limited to a safe value by starting resistors until a counter emf builds up in the armature. When the armature rotates in the magnetic field of the stator winding, the armature current begins to fall. The starter circuit now takes out some of the resistance in the armature circuit, and more current can be withdrawn from

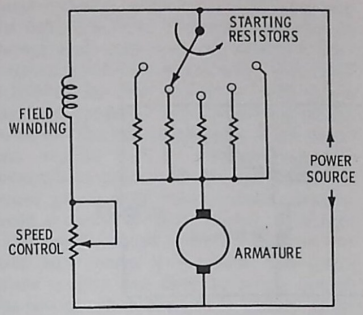


Fig. 9-15. Shunt-wound dc motor.

the source. The starting resistance is removed from the armature circuit step by step until it is all removed.

It is possible to control the motor speed by regulating the field current. When the magnetic field of the stator is reduced, less counter emf is generated as the armature winding rotates. As a result, the motor speeds up. The major advantage of the shunt motor is that its speed remains essentially constant under varying work load. It has a low starting torque, especially compared with that of the series motor; therefore, it is not suitable for starting under heavy loads. However, a complete removal of the load does not damage a shunt motor.

366. Describe the action and list the main characteristics of a series-wound dc motor.—In the series motor (Fig. 9-16), the field winding is in series with the armature and the supply voltage. When the power is turned on, a very high current exists, and strong magnetic fields are formed. The fields of the stator and armature windings oppose each other, causing the armature to rotate. As each pair of commutator segments makes contact with the brushes, the opposing field generated gives the armature another push, contacting a new pair of segments with the brushes. In this manner, the armature continuously rotates.

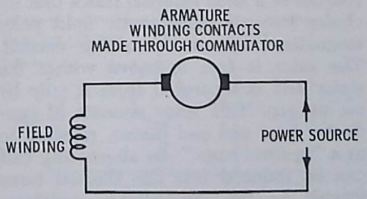


Fig. 9-16. Series-wound dc motor.

The series dc motor has a strong starting torque and starts quickly under load because of the strong initial currents present in the field winding and armature conductors. It is capable of delivering substantial power at low rotating speeds, but it does have a varying speed with a changing load. In fact, with no load the series motor will run at excessive speed, may be damaged, and can even throw itself apart.

367. What is meant by counter emf in a dc motor?—As the motor armature rotates in the magnetic field generated by the field winding, its conductors cut magnetic lines of force, and a voltage is generated in the armature winding. This voltage opposes in polarity the voltage of the power source. Such a counter emf has a bucking influence that limits the current in the armature. The speed of the motor can thus be controlled by regulating the strength of the magnetic field generated by the field winding.

368. Explain the principle of operation and list the main characteristics of a compound-wound dc motor, and explain how the speed is regulated.—A compound-wound dc motor is a modification of the shunt-wound type that includes an opposing series field winding (Fig. 9-17). As a result, a safe constant speed of operation can be obtained along with easy high-torque starting.

369. Draw simple schematic circuit diagrams showing three kinds of dc motors including a starting device.—See Figs 9-15 through 9-17.

370. What is the purpose of a commutator in a dc motor? In a dc generator?—In a dc motor, the commutator applies current of correct polarity to the armature windings as they rotate. The repelling influence of the armature and stator fields produces force which rotates the armature. In a dc generator, the commutator arrangement functions as a rec-

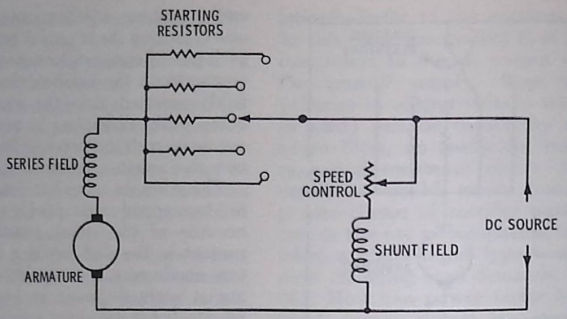


Fig. 9-17. Compound-wound dc motor.

tifier causing the current in the output circuit to be unidirectional.

371. What is the purpose of commutating poles or interpoles in a dc motor?—These minimize brush sparking caused by self-induction in the armature coils when the field is suddenly reversed in the commutating action. Additional poles with only a few turns of wire are added to the motor to counteract the self-induction.

372. What is the danger of operating a dc series motor without a load?—Too light a load on a series motor results in high-speed operation. This can build up until the motor breaks down.

373. Why is a series motor not used in radio power-supply motor-generators?—The major reason is its changing speed with changing load. The generator requires a constant speed.

374. Why is laminated iron or steel generally used instead of solid metal in the construction of the field and armature coils of motors and generators?—Such construction reduces strong circulating, or eddy, currents in the core. Less heat loss and higher efficiency also result.

375. If the field of a shunt-wound dc motor were opened while the machine was running under no load, what would be the probable result?—With no field, no counter emf would be generated in the armature circuit. Consequently, the armature would draw excessive current and would rotate at a very high speed that might damage the motor.

376. What would be the effects of a short circuit in an armature coil of a dc motor?—Possible results would be overheating as a result of high armature current, brush sparking, and loss of speed.

377. Name four causes of excessive sparking at the brushes of a dc motor or generator.—A shorting defect that causes the armature to draw excessive current, a defective armature coil, too heavy a load on the motor, corroded or worn-out brushes or commutators, or improper setting of the brushes.

378. If a 3-horsepower, 110-volt dc motor is 85% efficient when developing its rated output, what will be the line current?—The wattage of the motor is $3 \times 746 = 2238$ watts. The power law can be used to determine the line current, considering the efficiency of operation.

$$I_L = \frac{P/E}{E_{ff}} = \frac{2238/110}{0.85} = 23.9 \text{ amperes}$$

379. Explain the principle of operation of an induction motor and how such motors are started.—An induction motor consists of a fixed external stator that includes two electromagnetic field poles magnetized by an alternating current. The rotor is free to move within the stator and is separated from it only by an air gap. This rotor consists of conductor bars and end pieces, referred to as a "squirrel cage." An alternating emf can be induced into the shorted turns formed by the squirrel-cage construction. The strong current that results pro-

duces a strong counter field that opposes the induction field. This type of motor is started and continues in operation because of a rotating phase field. This field is formed by two additional field poles that are supplied with opposing-phase currents. The opposing-phase field windings can be fed by external two- or three-phase ac or with the use of an internal phase-shift combination, usually using a capacitor and resistor. It is this changing field that creates a pull on the rotor and causes it to rotate. The split-phase section can then be taken out of the circuit when the motor builds up to speed. Such a motor does not require a commutator and brushes, eliminating the radio noises that might result.

380. What determines the speed of a synchronous motor? An induction motor? A dc series motor?—The speed of synchronous and induction motors is a function of the power-line frequency and the number of poles. The speed of the induction motor is less than its synchronous speed and is also a function of the amount of loading. The speed of a dc series motor is a function of the supply voltage and the load.

381. What is the line current of a single-phase 7-horsepower ac motor when operating from a 120-volt line at full rated load, with a power factor of 0.8, and with 95% efficiency?—The total output power is $7 \times 746 = 5222$ watts. The power input, considering the 95% efficiency, is $5222/0.95 = 5497$ watts. Because of the power factor, the actual line current becomes:

$$I_L = \frac{P/E}{PF} = \frac{5497/120}{0.8} = 57.2 \text{ amperes}$$

382. Explain the principles of operation and list the main operating characteristics of a dc shunt generator and a dc compound generator. Explain how the voltage of a dc generator is controlled. Draw simple schematic diagrams of each of these types of generators.—See Fig. 9-18. The shunt dc generator has its field coil in parallel with the armature. The field coil consists of many turns of fine wire and places a light load on the output of the generator. Nevertheless, its magnetic force is sustained and can exert an effective control of the output voltage for a given armature speed. The stronger the field current (lower setting of the field control resistance), the greater is the magnetic force and the higher the output voltage. The shunt-type dc generator has reasonable regulation, the output voltage dropping to some extent as the load is further increased.

The compound generator also includes a series-connected field incorporating advantages of the series and shunt generator connections. This provides an even more constant output voltage and compensates for the tendency of the output voltage of a shunt generator to fall with increasing load. Output voltage is controlled in the same manner as for the shunt generator.

383. Describe the action and list the main characteristics of a series-wound dc generator.—A series dc generator is shown in Fig. 9-19. The field winding is in series with the armature winding and the load. The only time a series type of generator produces an output voltage is when a load is applied. With no load applied and no current through the field

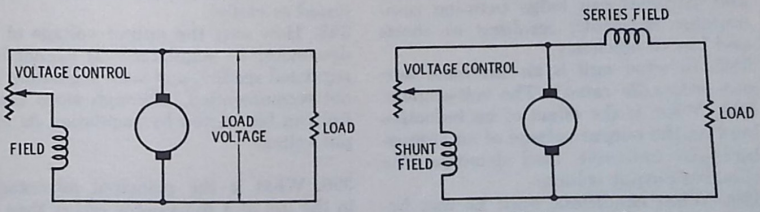


Fig. 9-18. Dc generators.

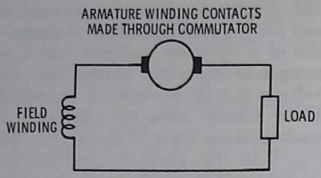


Fig. 9-19. Series dc generator.

coil, no energy is induced in the armature winding because its rotating conductors are not cutting any magnetic lines of force. Current is produced in the circuit whenever a load is connected. A strong magnetic field builds up about the field coil, and the rotating conductors of the armature then cut the lines of magnetic force. As a result, the generator voltage output rises. The series dc generator has poor regulation because its output voltage varies substantially with changes in the load.

384. Why are bypass capacitors often connected across the brushes of a high-voltage dc generator?—They remove the radio interference and noise generated by brush sparking. They also offer protection from high-voltage surges.

385. How may the radio-frequency interference often caused by sparking of the brushes of a high-voltage generator be minimized?—By proper care and positioning of the brushes. A low-pass filter in the power line or capacitors across the brushes will minimize rf interference. Also, rf chokes in the power line can prevent radiation of sparking noises from the distribution line.

386. Why should emery cloth never be used to clean the commutator of a motor or generator?—It can be abrasive, and particles can lodge between commutator segments, resulting in shorts and loss of efficiency.

387. In what unit is an alternator output ordinarily rated?—The volt-ampere.

388. What is the effect of an inductive load on the output voltage of an alternator?—An inductive load decreases the effective output voltage.

389. What conditions must be met before two ac generators can be operated in parallel?—In general, the output voltages, phase, and frequencies must be matched and compensated.

390. When starting a large dc motor-generator set, what adjustment should be made to the motor-field rheostat?—Set it to its minimum resistance position, which develops maximum counter emf.

391. What may be the trouble if a motor-generator fails to start when the start button is depressed?—There are various possibilities, such as a defect in the switching and circuit-breaker circuit, an open fuse, a defective armature or field, or bad brushes.

392. What may cause a motor-generator bearing to overheat?—Overload, misalignment, or inadequate lubrication.

393. When increased output voltage is desired from a motor-generator set, what is the usual procedure?—Most commonly, the voltage is regulated by the series rheostat of the generator field.

394. Describe the construction of a dynamotor. What are its operating characteristics?—A dynamotor is a motor-generator single-shaft combination with a single common field for both motor and generator. The motor usually operates from a 6-, 12-, or 28-volt dc source. The generator supplies a high dc output suitable for providing plate power to vacuum-tube circuits. There is a common armature with separate windings and commutators for the motor and generator sections.

The dynamotor provides an economical and compact unit for radio installations. It has fair regulation, and because of its high speed, it delivers the necessary power for operating small transmitters at good efficiency. Its efficiency is higher than for a motor-generator, but its operating conditions cannot be adjusted as easily.

395. How may the output voltage of a dynamotor be regulated?—It cannot be regulated readily, and such regulation is not recommended, although some control can be exerted by regulating its input voltage.

396. What is the principal advantage in the use of a dynamotor rather than a motor-generator to furnish plate power to a small mobile transmitter? Principal

disadvantage?—The advantage is its small size and good operating efficiency. It is not as well regulated as a motor-generator set, and its output voltage is largely dependent on input voltage conditions.

CHAPTER 10

Radiotelegraph Transmitters and Antennas, Element 6

TRANSMITTERS

397. Define type A1, A2, A3, A4, and B emissions.—Refer to RR 2.201. Emission A1 is radiotelegraphy without the use of a modulating audio frequency. It is a continuous rf carrier transmission with the information conveyed by keying the rf carrier on and off. Type A2 emission is radiotelegraphy by the on-off keying of an amplitude-modulating audio frequency or audio frequencies, or by the on-off keying of the modulated emission. Type A3 emission is amplitude-modulated radiotelephony; A4 is facsimile transmission. Type B emission is transmission using damped waves. This type of transmission has the characteristics of the old spark transmitters; the keyed radio-frequency wave diminishes in amplitude during each interval that the key is held down.

398. Draw a block diagram of a mopa radiotelegraph transmitter with the master oscillator operating on 2017.5 kHz and the transmitter output on 8070 kHz—Mopa stands for master oscillator–power-amplifier. In the arrangement of Fig. 10-1, a pentode crystal oscillator is used with its plate resonant circuit tuned to twice the crystal frequency. A doubler stage follows to obtain a total multiplication of four ($4 \times 2017.5 = 8070$). The final stage is a power amplifier, needed to build up the power level of the transmitted signal.

399. What are the disadvantages of using a self-excited–oscillator type of transmitter for shipboard service?—Frequency instability is the major disadvantage. Frequency drift is a particularly troublesome disadvantage when there is poor regulation on the power-supply lines, because a change in supply voltage can result in a substantial change in frequency when self-excited oscillators are used. A swinging antenna can cause a frequency change.

400. What is the principal advantage to be gained from the use of a crystal-controlled oscillator in a marine radiotelegraph transmitter?—The principal advantage is frequency stability.

401. A station has an assigned frequency of 8000 kilohertz and a frequency tolerance of ±0.04%. The oscillator operates at ⅛ the output frequency. What is the maximum permitted deviation of the oscillator frequency, in hertz, which will not exceed the tolerance?—The permissible frequency drift at 8000 kilohertz is:

$$0.0004 \times 8000 = 3.2 \text{ kHz}$$

A factor to be considered when establishing the tolerance of the crystal is the extent of the multiplication. Frequency-multiplying systems multiply the possi-

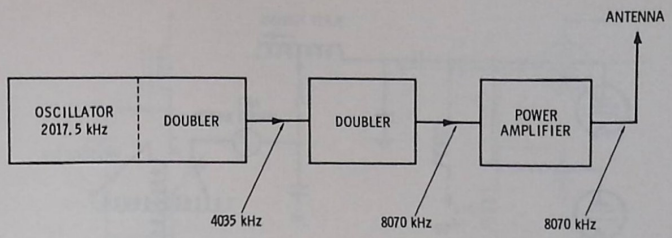


Fig. 10-1. Block diagram of mopa radiotelegraph transmitter.

ble drift as well as the crystal frequency. If the crystal frequency is multiplied by a factor of eight, there will be like multiplication of any drift in the crystal frequency. Therefore the tolerance of the crystal-oscillator frequency becomes:

$$\frac{3200 \text{ hertz}}{8} = 400 \text{ hertz}$$

402. A transmitter is operating on 5000 kHz, using a 1000-kHz crystal with a temperature coefficient of −4 hertz/megahertz/degree C. If the crystal temperature increases 6°C, what is the change in the output frequency of the transmitter?—The crystal has a negative temperature coefficient, and therefore its frequency decreases with an increase in temperature. Since the frequency changes at a rate of 4 hertz per megahertz with each degree change, the total change will be 24 hertz ($6 \times 4 \times 1$).

Since the frequency has been multiplied by a factor of 5, so will the frequency drift. Therefore, the actual decrease in the transmitter output frequency becomes:

$$24 \times 5 = 120 \text{ hertz}$$

Therefore, the transmitter frequency becomes:

$$5000 - 0.120 = 4999.88 \text{ kHz}$$

403. What is the crystal frequency in a transmitter having three doubler stages and an output frequency of 16,870 kHz?—Three doubler stages produce a multiplication of $2 \times 2 \times 2 = 8$. Therefore, the crystal frequency is:

$$\frac{16870}{8} = 2108.75 \text{ kHz}$$

404. Discuss the advantages and disadvantages of self-excited–oscillator and master-oscillator–power-amplifier transmitters.—The advantages of a self-excited–oscillator transmitter are simplicity, parts economy, and limited power demand. Its disadvantage is frequency instability, with even an antenna swinging in the breeze causing frequency change. A major advantage of the mopa (master-oscillator–power-amplifier) type is its frequency stability. The oscillator can be operated at relatively low power, and it is effectively isolated from the antenna system by the power amplifier. More parts are required, and there is a higher power supply current demand.

405. What is the primary function of the power-amplifier stage of a marine radiotelegraph transmitter?—Its purpose is to increase the power level of the radio-frequency carrier. It builds up the weak signal from the preceding stage to the power level needed to drive the antenna system.

406. What class of amplifier should be employed in the final amplifier stage of a radiotelegraph transmitter for maximum plate efficiency?—The amplifier should be operated class C.

407. Draw a simple schematic diagram showing a method of coupling the radio-frequency output of the final power-amplifier stage of a transmitter to an antenna.—See Fig. 10-2.

408. What is the purpose of a buffer amplifier stage in a transmitter?—It isolates the power amplifier from the oscillator, overcoming the influence that the power amplifier or antenna system has on the frequency of the transmitted carrier.

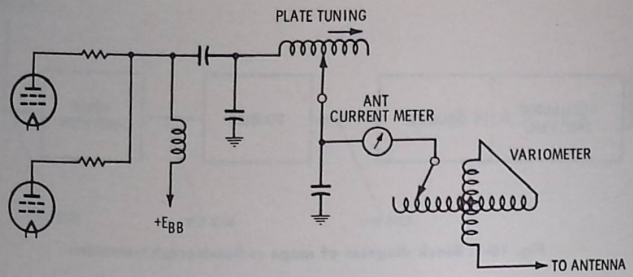


Fig. 10-2. Coupling of rf power amplifier to antenna.

409. How may instruments used to indicate various direct currents and voltages in a transmitter be protected against damage due to stray rf energy?—Protection is offered by rf bypass capacitors and radio-frequency chokes. The most common method is the use of an rf bypass capacitor connected to ground just ahead of the meter or across the meter itself (Fig. 10-3). A radio-frequency choke ahead of the meter also acts as a radio-frequency block. An additional consideration is the proper shielding of the meter with a grounded case and the use of shielded leads for connecting to the meter terminals.

410. Draw a simple schematic diagram of a key-click filter suitable for use when a vacuum-tube transmitter is keyed in the negative high-voltage circuit.—See Fig. 10-4. This most common key-click filter consists of a series inductor along with a capacitor or resistor-capacitor combination connected across the key. Abrupt circuit interruptions, especially in the line associated with high voltage, generate spurious modulation components that are audible in the form of key-clicks and produce a wider than normal emission bandwidth. Inductor-capacitor and resistor-capacitor combinations are used to filter out these components.

411. Draw a simple schematic diagram showing how a radiotelegraph transmitter may be keyed by the grid-blocking method.—See Fig. 10-5. The idea of grid-block keying is to apply cutoff bias to the radio-frequency power amplifier when the key is up. The key-down position applies normal class-C bias, and radio-frequency output results.

412. Does the code speed (number of words per minute) transmitted have any

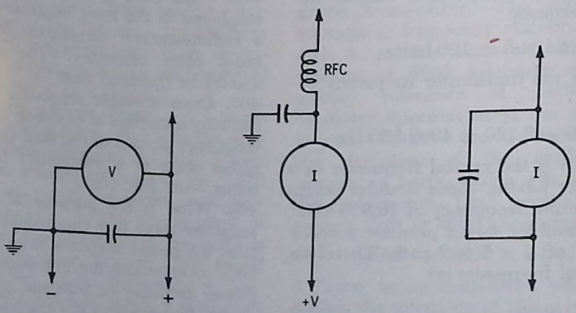


Fig. 10-3. Meter protection arrangements.

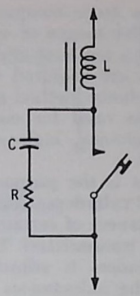


Fig. 10-4. Key-click filter.

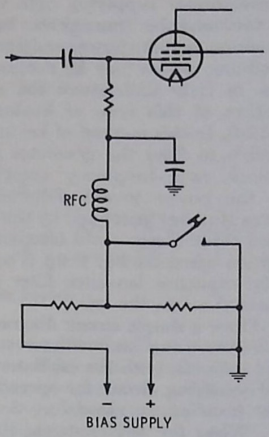


Fig. 10-5. Grid-block keying circuit.

effect on the bandwidth of the emission from a radiotelegraph transmitter?—Yes. The faster one keys the transmitter, the more rapidly and frequently the carrier is interrupted. In effect, there are more changes per second, and the frequency components generated by the keying process become higher. A greater emission bandwidth is needed with rapid keying as compared to slow keying.

413. Why should all exposed metal parts of a transmitter be grounded?—Such grounding reduces the shock hazard and increases efficiency and stability. Exposed metal parts can accumulate charges from nearby components. In high-voltage circuits, these charges can become excessive, and personnel can be harmed by electric shock, or their reflex reaction to shock can result in bodily injury.

414. Draw a simple schematic diagram of a system of keying in the primary of

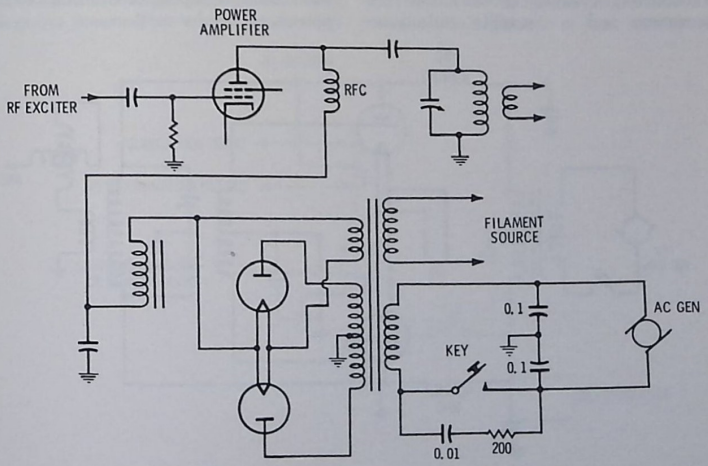


Fig. 10-6. Primary keying system.

the transformer supplying high voltage to a vacuum-tube transmitter. Indicate any values of inductance, resistance, or capacitance which may be deemed necessary to fully understand the correct operation of this type of keying.—See Fig. 10-6. In this method of keying, it is advisable to filter the generator output to block radio-frequency components from the power source. Filtering also reduces rf noises generated by the power source; these noises could interfere with reception when the key is up. The usual resistor-capacitor key-click filter is also connected across the key.

415. Draw a simple circuit diagram of a transmitter using an oscillator coupled to the antenna, with the oscillator using a self-rectifying circuit for operation directly from an ac generator.—See Fig. 10-7. When the key is down, this old type of transmitter applies positive voltage alternately to the two anodes of the oscillator in the form of pulsations (half sine waves). Thus the emitted radiation, although it is keyed, also has an audible tone which is twice the frequency of the ac power source. This is a form of A2 emission.

416. Why do many marine transmitters employ variometers rather than variable capacitors as the tuning elements?—The transmitters operate at very low frequencies, and a variable inductance supplies a more compact, economical, and effective means of varying the frequency of a resonant circuit. Only fixed capacitors are required with the variable-inductance method of tuning, eliminating the need for costly and large high-capacitance, high-voltage variable capacitors.

417. What is the purpose of the iron-compound cylinders which are found in the inductances of certain marine radiotelegraph transmitters? The position of these cylinders is adjustable with respect to the inductances for what purpose?—The iron cores permit high inductance and high-Q resonant circuits. These cores can be made adjustable for changing the frequency of associated resonant circuits.

418. Draw a circuit diagram showing the principle of operation of a telegraph keying relay.—See Fig. 10-8. When the key is down, the battery current energizes the relay. The armature is pulled down, and the relay contacts close, supplying a return path to ground for the dc voltage source that provides plate power to the transmitter rf amplifier. This causes rf energy to be applied to the antenna system for the duration of the key-down interval. Releasing the key removes current from the relay, and the contacts open, switching off the power.

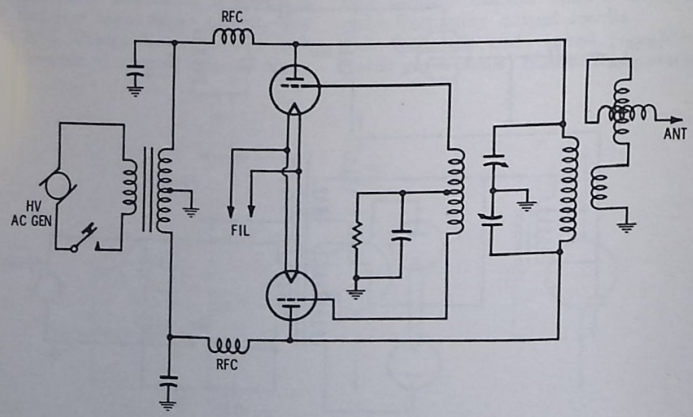


Fig. 10-7. Transmitter using self-rectifying oscillator.

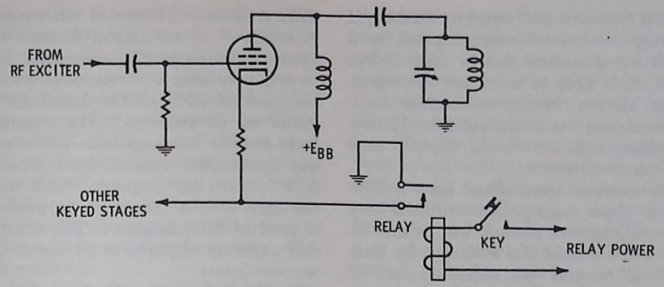


Fig. 10-8. Use of a relay for keying.

419. What is meant by self-wiping contacts as used in connection with relays?—Instead of striking-type contacts, they are sliding types that provide clean action and avoid the pitting condition that is prevalent with striking-type contacts.

420. What material is frequently used for relay contacts? Why?—Metals preferred are those that have low contact resistance and do not readily corrode or pit. Typical metals are tungsten, silver, and special alloys.

421. Show by a diagram how a radiotelegraph transmitter can be keyed by the use of a keying relay.—See Fig. 10-8.

422. List the various points in a radiotelegraph transmitter where keying can be accomplished.—The most common places are the plate supply line, power-transformer primary, cathode return path, or grid-bias circuit. Refer to Figs. 10-5, 10-6, and 10-8.

423. What is meant by break-in operation at a radiotelegraph station, and how is it accomplished?—Refer to Fig. 10-9. In the break-in keying procedure, a relay switches the antenna system between transmitter output and receiver input simultaneously with the switching on and off of the transmitter and receiver. When the key is down, the antenna connects to the transmitter output; when the key is up, the antenna is connected to the receiver input. Such an arrangement permits a fast changeover

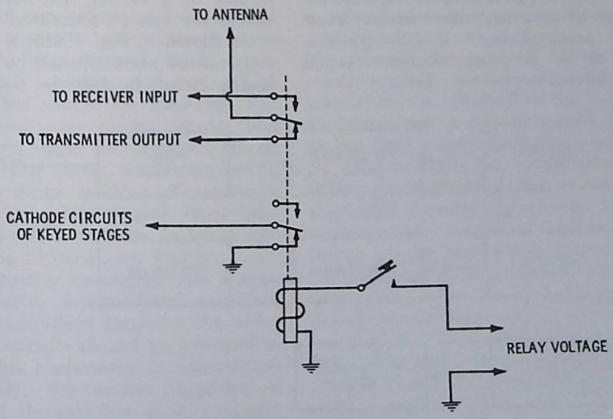


Fig. 10-9. Break-in keying system.

between transmit and receive. In fact, if receiving conditions become poor, or if the receiving station misses some information, it is able to interrupt the transmitting station before additional message material is transmitted. Hence, corrections can be made rapidly and with less confusion.

424. A marine transmitter uses a 500-hertz ac plate supply. It is rectified by a full-wave rectifier circuit but is not filtered. How would the emission be classified?—It would be classified as A2 emission because the actual plate supply voltage would be pulsations instead of pure dc. Therefore, in the keying process, a 1000-hertz modulating component would be transmitted. In this case, the keying is, in effect, tone-modulated.

425. What is meant by a self-rectified circuit, as employed in marine vacuum-tube radiotelegraph transmitters?—In this manner of transmission (Fig. 10-7), the ac wave is applied directly to the anode of the transmitter tube. Since the tube can only conduct during the positive alternation, it is in effect acting also as a rectifier. The ac power variations are not filtered and result in a form of A2 emission producing an output that has a tone-modulation component corresponding to twice the frequency of the ac power source.

426. How is the keying of a simple oscillator of an emergency marine transmitter accomplished?—Usually the primary of the ac power source is keyed (Fig. 10-7).

427. A storage battery of what capacity is required to operate a 50-watt emergency radiotelegraph transmitter for six hours, assuming a continuous transmitter load of 70% of the key-locked demand of 40 amperes? The emergency light load is 1.5 amperes.—The continuous transmitter current load would be $0.70 \times 40 = 28$ amperes. Add to this the light load of 1.5 amperes, producing a total of 29.5 amperes. The total battery capacity required is $29.5 \times 6 = 177$ ampere-hours.

428. What is meant by frequency-shift keying, and how is it accomplished?—Refer to Fig. 10-10. In the frequency-shift keying method, the rf output is of one frequency when the key is down and shifts to another frequency when the key is up. Usually, this technique is used for high-speed transmission and provides a better signal-to-noise ratio per transmitted bandwidth. For conventional keying, no signal is transmitted during the key-up time.

In regular cw code transmission, the carrier is turned off during the spaces and on during the marks (dots and dashes). In fsk, by using one frequency for the spaces and a second frequency for the marks, the carrier can be kept on at all times. Inasmuch as the mark and space frequencies can be positioned near each other, the receiver remains under control of a carrier whether marks or spaces are being transmitted.

As shown in Fig. 10-10, a frequency shift can be accomplished by using the keying circuit to shift the frequency of

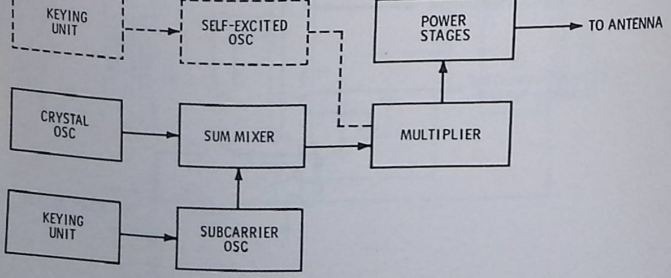


Fig. 10-10. System for frequency-shift keying.

a self-excited transmitter oscillator between two predetermined frequencies. More often, the frequency shift is accomplished by a reactance tube. The reactance tube is used to frequency shift a low-frequency subcarrier oscillator. The output of this oscillator is then mixed with a crystal-controlled component to permit keying at a much higher frequency. A series of multipliers then builds up the frequency-shift signal to the desired transmitting frequency. This is F2 emission.

429. What are the general characteristics of the emission of a radiotelegraph transmitter which uses a chopper to obtain A2 emission?—During the period that the key is held down, the carrier is interrupted at a high audio rate (400-800 hertz) by the chopper switching action. This is another means of obtaining audio tone modulation for A2 emission. When the key is up, the carrier is off; when the key is down, the carrier is on but is interrupted at the chopper rate.

430. What type of modulation is largely contained in static and lightning radio waves?—The dominant type of modulation in static and lightning electromagnetic waves is amplitude modulation. The dominant wave polarization is vertical.

TUNING AND TROUBLES

431. What precautions should be observed in tuning a transmitter to avoid damage to components?—Each transmitter has a recommended tuning procedure. This should be followed. The most common procedures require that one or more stages be tuned at reduced power, or that power not be applied to a specific stage without rf excitation from the preceding stages. These precautions prevent damage to tubes and overloading of the power supply.

432. Suppose a transmitter has a master oscillator, intermediate amplifier, and final amplifier. Describe the order in which circuits should be adjusted in placing this transmitter in operation.—Customarily, the master oscillator is tuned and checked first. If it is supplying adequate excitation to the intermediate power amplifier, one can then proceed to tune the ipa. Sometimes the initial tuning of the ipa stage is done at reduced power. If the ipa is also used as a frequency multiplier, it is wise to check its output frequency to make certain that the output resonant circuit has been tuned to the correct harmonic. The final power amplifier is tuned only after proper rf excitation has been obtained from the intermediate amplifier. The next step is neutralization, if that is required, for the power amplifier. The power amplifier is almost always tuned initially at reduced power. The plate circuit must be resonated correctly, and the recommended tuning procedure for the antenna coupling system must be followed. Finally, full power is applied to the power amplifier and touch-up adjustments are made. It is now advisable to check the rf power output and dc power input to make certain that the transmitter is operating efficiently and without placing an improper demand on the power supply. A final check would be to monitor the quality of the transmitted signal and also the quality of the keying.

433. Why should a transmitter be tuned initially at reduced power?—To prevent damage to components, especially power tubes, and to avoid placing an excessive demand on the power supply, which can cause a blown fuse and overheating or damage to power-circuit components.

434. Should the antenna circuit of a master-oscillator–power-amplifier type of transmitter be adjusted to the resonant frequency before the plate tank circuit of the final stage? Give the reason(s) for your answer.—This is not advisable. When the antenna system is tuned to resonance, it places the greatest load on the transmitter output. If the plate tank circuit has not been tuned to resonance, this excessive load results in an excessively high plate current, which can damage the power-amplifier tube and/or overload the dc supply-voltage source.

435. What is the effect of excessive coupling between the output circuit of a simple oscillator and an antenna?—Two problems can result. Excessive load may

be reflected and prevent the stage from oscillating, completely shutting down the transmitter. Excessive coupling can also make the oscillator frequency vary excessively. The oscillator plate current may exceed the safe value.

436. How is the power output of a marine vacuum-tube radiotelegraph transmitter ordinarily adjusted?—A switching arrangement in the primary of the transformer of the plate power supply is used to regulate the transmitter power output. Usually, proper transmitter output is indicated when the transmitter draws normal plate current for a prescribed value of plate voltage and or antenna current.

437. If the plate current of the final radio-frequency amplifier in a transmitter suddenly increases and radiation decreases, although the antenna circuit is in good order, what would be the possible causes?—A principal cause of this type of disturbance is the loss of rf excitation to the final rf power amplifier. Check the preceding stages to make certain that they are delivering proper excitation to the final. A defective power-amplifier stage is another possibility. The tube may have become gassy. If external grid bias is being used, its loss could also cause a jump in plate current and inefficient operation of the stage. Similar improper operating conditions could occur if resistor-capacitor coupling is used from the preceding stage and the coupling capacitor has excessive leakage, placing a continuous positive bias on the grid of the final power amplifier.

438. Name four indications of a defective vacuum tube in a transmitter.—Improper blue gas glow within the tube, too little output accompanied by either excessive or abnormally low plate current, filament off with normal filament-circuit continuity and voltage, and internal arcing and/or plate-current instability.

439. What may cause a radio-frequency amplifier tube to have excessive plate current?—Gas within the tube or an interelectrode short. External influences that commonly cause this defect are loss of insufficient rf excitation to an rf power amplifier, improper or missing grid bias, and improper tuning and loading of the output circuit.

440. In a series-fed plate circuit of a vacuum-tube amplifier, what would be the result of a short circuit of the plate bypass capacitor?—Such a short would remove the plate voltage from the vacuum tube, and the output would be lost. The short would place an excessive current demand on the supply-voltage source, overheating dropping and decoupling resistors or blowing the power-supply fuse.

441. In a shunt-fed plate circuit of a vacuum-tube amplifier, what would be the result of a short circuit in the plate rf choke coil?—The shorted choke will place an rf ground at the plate. The resultant detuning and shorting of the plate resonant circuit at the rf frequency results in an excessive plate current and a loss of rf output.

442. Describe a means of reducing sparking at the contacts of a key used with a radiotelegraph transmitter.—A shunt capacitor or a suitable key-click filter will eliminate this problem.

443. What will be the effect of a swinging antenna upon the output of a self-excited–oscillator transmitter? A master-oscillator–power-amplifier transmitter?—The swinging antenna will result in frequency instability when a self-excited–oscillator transmitter is used. For a mopa combination, it will not have an adverse influence on frequency. The power-amplifier stage not only increases the power output of the transmitter but also acts as an isolation stage between the oscillator and antenna system. Occasionally, there may be some slight change in loading as indicated by a slight variation of the power-amplifier plate current.

444. What is indicated if a voltmeter connected between the negative side of a ship's dc line and ground reads the full line voltage?—It suggests that the positive side of the ship's line operates at ground potential.

445. What is meant by harmonic radiation?—This refers to the radiation of a signal from the transmitter and antenna system on a frequency that is some har-

monic of the desired transmitting frequency of the station.

446. Why does harmonic radiation from a transmitter sometimes cause interference at distances from the transmitter where the fundamental signal cannot be heard?—The harmonic frequency is always higher than the fundamental frequency because it is some whole multiple of the fundamental. Consequently, it may be on some frequency that is suitable for skip propagation. As a result, it returns to the earth at a distance beyond the range of transmission of the fundamental-frequency signal.

447. What is the primary reason for the suppression of radio-frequency harmonics in the output of a transmitter?—The primary reason is to prevent interference to other services on frequencies which are whole-number multiples of the desired transmitting frequency.

448. How may harmonic radiation of a transmitter be prevented?—Harmonic radiation is reduced by proper tuning of the transmitter, insertion at the transmitter of a low-pass filter that rejects harmonics of the fundamental frequency, and the use of an antenna that is not an efficient radiator on the harmonic frequencies. A Faraday shield between the plate resonant circuit and the antenna coupling circuit is also effective in preventing the transfer of harmonic components to the antenna system.

449. In a radiotelegraph transmitter employing a dc generator as the source of plate voltage, an ac generator as the filament supply, and grid-bias keying, if it is noted that when the key contacts are open the emission continues, what could be the trouble?—A possibility is insufficient or missing grid-blocking bias.

ANTENNAS

450. Draw a sketch of a typical shipboard antenna for transmitting on 500 kHz. Show the supporting insulators, the safety link, and the lead-in wire. How does voltage vary along the length of the lead-in and along the antenna?—Refer to Fig. 10-11. The rf voltage is maximum at the far end of the antenna. This is also a minimum-current point. Going back along the antenna toward the transmitter, the voltage decreases and the current increases. An electrical

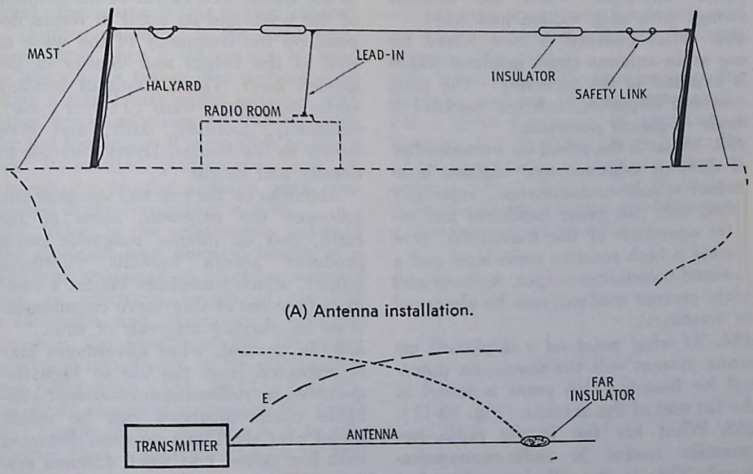


Fig. 10-11. Shipboard main antenna.

quarter wavelength back along the antenna lead-in line, there will be a maximum-current and minimum-voltage point. Antenna length is usually an electrical quarter wavelength or less. The regular antenna is more often a quarter wave, while the emergency antenna is less.

Beyond the strain insulator at each end of the antenna, there is a safety link. At this point, the tight segment of wire is of less strength than the antenna wire, and if the antenna is put under great stress it will break at one of these links. If this happens, the antenna will sag, but it will not fall because the safety-link wire is strong. Later, in more suitable weather, the safety link can be replaced.

451. What care should be taken in hoisting the antenna of a shipboard radiotelegraph station to avoid damage to the antenna wire and insulators?—The pulling up of the antenna should be done slowly and with care to prevent the insulators from being shattered against hard surfaces and to prevent the antenna wire itself from being twisted or kinked. Keep the wires clear of metallic and other surfaces to prevent unstable operation when the antenna swings with ship motion and wind.

452. What material is best suited for use as an antenna strain insulator which is exposed to the elements?—The most common shipboard antenna insulator is made of glazed porcelain.

453. What is the effect on a transmitter of dirty or salt-encrusted antenna insulation?—Such contamination, especially when wet, can cause inefficient and erratic operation of the transmitter, producing a high receiver noise level and a lowered transmitter output. Antenna and plate current readings can be abnormal or erratic.

454. At what point on a shipboard antenna system will the maximum potential be found?—This point is found at the far end of the antenna (Fig. 10-11).

455. What are the lowest radio frequencies useful in radio-communications?—This is the vlf (very low frequency) spectrum extending below 30 kHz. The minimum useful frequency falls somewhere between 10 and 15 kHz.

456. What radio frequencies are useful for long-distance communications requiring continuous operation?—The vlf and lf frequency spectra come under this classification. Substantial power and massive antenna systems are required, especially by the shore stations. The low-frequency end of the mf spectrum (around 500 kHz) is effective for medium-distance marine radiotelegraph communications.

457. What frequencies have substantially straight-line propagation characteristics analogous to those of light waves and unaffected by the ionosphere?—These are the vhf (very high frequency) and uhf (ultrahigh frequency) spectra and the microwave frequencies above 3000 MHz. The low-frequency limit is approximately 30 MHz.

458. What effect do sunspots and aurora borealis have on radio-communications?—Sunspots have a direct influence on the degree of ionization of the upper atmosphere of the earth and also the height of the various ionized layers. A radio wave entering these layers is reflected back to the earth and returns at a distance far removed from the source of the signal. The extent of the bending of the wave and its point of return depend on the frequency of the wave as well as the height and density of the ionized layer. The amount of bending varies on a yearly basis (11-year cycle), seasonally, monthly, daily, and even hourly as the ionized layers fluctuate in density and height.

Activities on the sun and sunspots also influence the magnetic fields of the earth, and an intense magnetic storm produces aurora borealis (northern lights), which sometimes causes a complete fade-out of shortwave communications for varying intervals of time.

459. In general, what advantages may be expected from the use of high frequencies in radiocommunications?—Reliable communications can be established over short and medium distances with low power and small antenna systems. Direct wave propagation of this type is reliable, especially when aided by high-gain directional antennas which

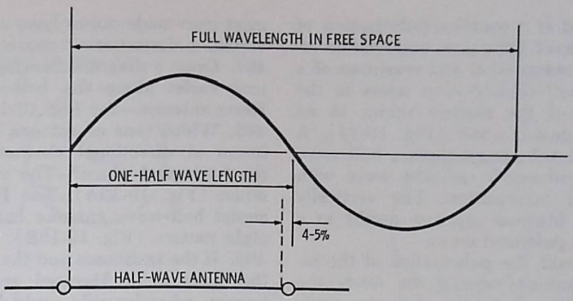


Fig. 10-12. Half-wave Hertz antenna.

can be made much smaller in size then they can for long-wave operation. A major advantage of high-frequency transmissions is the fact that the antenna systems are small and can be mounted conveniently on moving vehicles.

Studies of propagation over the years have also made long-distance communications feasible (shortwave broadcast stations for example). This is done by proper selection of frequency, power, and direction of transmission to match changing conditions of the ionosphere.

460. Why is an artificial antenna sometimes used in testing a transmitter? By what other name is this device known?—"Dummy antenna" is the most common name. Such a device can be used to check out a transmitter without radiating a signal that might interfere with other communications on the transmitter test frequency. It is possible to check out transmitter performance just as though the regular antenna were connected to the transmitter output.

461. What is the relationship between the electrical and physical length of a Hertzian antenna?—A Hertzian antenna has an electrical length of one-half wavelength, and, therefore, it is about one-half the length of the free-space electrical wavelength of the corresponding radio wave (Fig. 10-12). Actually, to obtain electrical resonance, the physical length of the antenna is 4 to 5% shorter than a half wavelength in free space.

462. What would be the effect on the resonant frequency if the physical length of a Hertzian antenna were reduced?—The resonant frequency would be increased. The shorter the antenna, the higher is its resonant frequency.

463. What is the effect on the resonant frequency of connecting a capacitor in series with an antenna? An inductor in series with an antenna?—A capacitor in series increases the resonant frequency; an inductor in series decreases the resonant frequency.

464. If you desire to operate on a frequency lower than the resonant frequency of an available Marconi antenna, how may this be accomplished?—To operate on a lower frequency, add an inductor in series with the Marconi antenna (Fig. 10-13).

465. What is the difference between the Hertzian and the Marconi antennas?—For a given frequency of operation, a Hertzian (or Hertz) antenna (Fig. 10-12) is about twice as long as a Marconi antenna (Fig. 10-13). The Hertz is a half-wavelength antenna; the Marconi is a quarter-wavelength antenna.

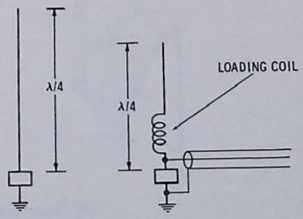


Fig. 10-13. Use of loading coil to increase electrical length of short antenna.

466. What is meant by polarization of a radio wave? How does polarization affect the transmission and reception of a radio wave?—Polarization refers to the direction of the electric vector of an electromagnetic wave (Fig. 10-14). A horizontal antenna, such as a half-wave Hertz, produces a radiated wave with horizontal polarization. The vertically mounted Marconi antenna results in a vertically polarized wave.

In general, the polarization of the receiving antenna should be made the same as the polarization of the transmitting antenna if there is to be maximum received signal. (An exception to this rule is related to ionospheric propagation, which usually results in a mixed polarization of the reflected wave.) When very low antennas are used, especially when installed on mobile equipment, vertical polarization is preferred and usually results in more reliable communications. In medium- and long-distance communications, the high horizontal antenna is favored more often. Vertically polarized antennas are often subject to more noise pickup because most man-made noises have a dominant vertical polarization.

467. Draw a diagram showing how current varies along the half-wavelength Hertz antenna.—See Fig. 10-14A.

468. Which type of antenna has a minimum of directional characteristics in the horizontal plane?—The vertical antenna (Fig. 10-15A). The Hertz horizontal half-wave antenna has a figure-eight pattern (Fig. 10-15B).

469. If the resistance and the current at the base of a Marconi antenna are known, what formula could be used to determine the power in the antenna?—Use the power-law equation:

$$P_A = I_A^2 R_A$$

One must remember that the antenna resistance is the radio-frequency resistance and is a quantity that cannot be measured with a conventional ohmmeter.

470. What should be the approximate series impedance of a quarter-wave matching line used to match a 600-ohm feed to a 70-ohm antenna?—Refer to

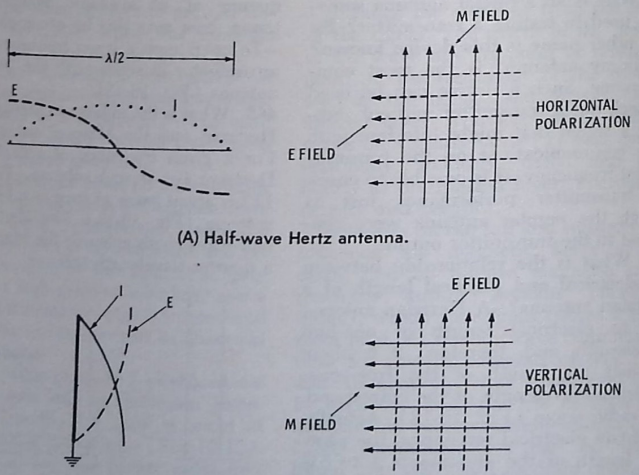
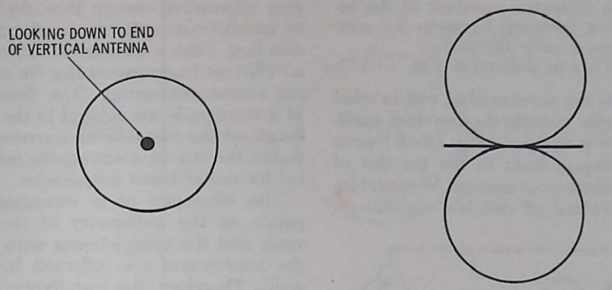


Fig. 10-14. Voltage and current distribution and polarization for horizontal and vertical antennas.



(A) Vertical antenna. (B) Horizontal antenna.

Fig. 10-15. Antenna patterns in horizontal plane.

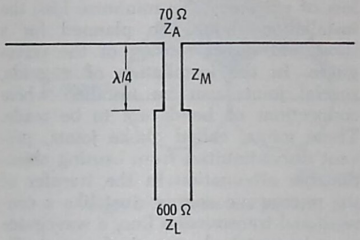


Fig. 10-16. Quarter-wave matching section.

Fig. 10-16. The basic matching equation is:

$$Z_M = \sqrt{Z_L Z_A}$$

By substitution:

$$Z_M = \sqrt{600 \times 70} = 205 \text{ ohms}$$

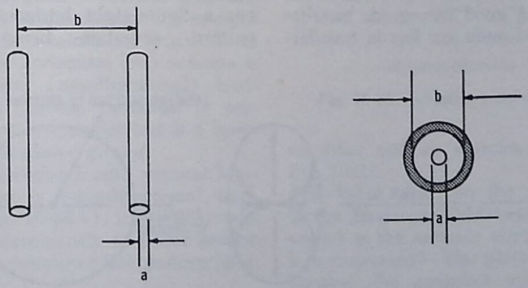
471. What determines the surge impedance of a two-wire, nonresonant radio-frequency transmission line?—The surge impedance of a transmission line depends on the conductor diameter, the conductor spacing, and the dielectric constant of the insulating material separating the conductors. The equations for the two common types of line in Fig. 10-17 are:

$$Z_0 = 276 \frac{\log \frac{b}{a}}{\sqrt{K}} \text{ (Open-wire line)}$$

$$Z_0 = 138 \frac{\log \frac{b}{a}}{\sqrt{K}} \text{ (Coaxial line)}$$

where,

Z_0 is the surge impedance,



(A) Parallel. (B) Coaxial.

Fig. 10-17. Surge impedance of transmission lines.

K is the dielectric constant of the insulating material between the conductors (unity for air),
a and b are as defined in Fig. 10-17.

472. What are waveguides, and in what type of radio circuits do they find application?—Waveguides (Fig. 10-18) serve as transmission lines in the transfer of uhf and microwave energy. Waveguides are constructed of durable weather-resistant metals capable of reflecting microwave energy with a minimum of loss. The cross section of a waveguide can be rectangular or circular. There is no inner conductor, and the radio-frequency energy propagates along the waveguide enclosure much as a radio wave is propagated through space. However, the energy is confined within the walls of the waveguide. A good waveguide installation has very much less loss in transferring microwave energy than do coaxial or parallel-conductor types of transmission line. Thus a waveguide functions as an efficient transmission line for conveying microwave energy. The dimensions of a waveguide are related to the wavelength of the signal to be conveyed; this makes the size of a waveguide impractical for use at lower frequencies.

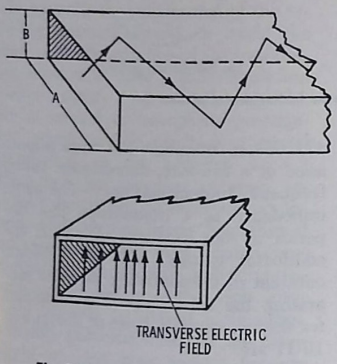


Fig. 10-18. Rectangular waveguide.

The efficiency of a waveguide depends on the uniformity of the inner walls and the completeness with which the microwaves are reflected from the walls. Therefore, the installation should be such that the interior is kept clean, smooth, and dry. Water, dust, and corrosion will introduce discontinuities and loss of efficiency. To minimize loss, the installation should be planned for a short and direct routing of the waveguide. In the installation of a guide, special joints can be installed where connections or bends are to be made. These joints, called choke joints, prevent discontinuities from causing objectionable attenuation in the transfer of the microwave energy. Just like a conventional transmission line, a waveguide must be matched properly for most efficient operation. It must be correctly dimensioned relative to the frequency range that is to be conveyed.

473. Describe the directional characteristics, if any, of the following types of antennas: (A) horizontal Hertz antenna, (B) vertical Hertz antenna, (C) vertical loop antenna, (D) horizontal loop antenna, (E) vertical Marconi antenna.—The horizontal Hertz antenna has a figure-eight horizontal radiation pattern, radiation being maximum

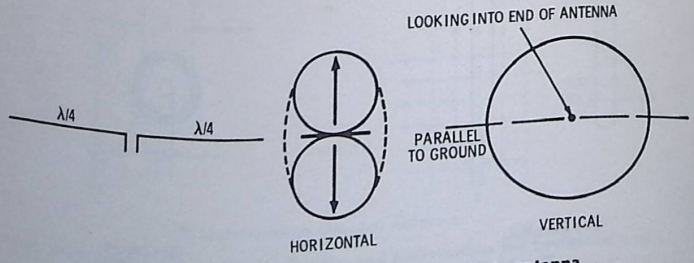
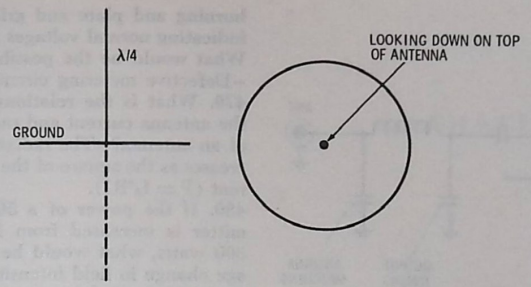
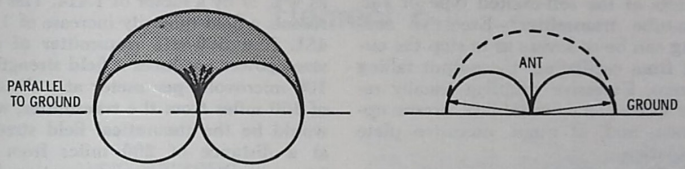


Fig. 10-19. Radiation patterns of half-wave Hertz antenna.



(A) Horizontal pattern.



(B) Vertical patterns.

Fig. 10-20. Radiation patterns of quarter-wave vertical Marconi antenna.

broadside to the antenna. The vertical radiation pattern in free space is circular (Fig. 10-19).

The half-wavelength vertical antenna (rarely called a vertical Hertz) has a circular (omnidirectional) horizontal radiation pattern. Its vertical radiation is predominantly at low angles, with some higher-angle lobes.

The low-frequency vertical loop antenna has a bidirectional figure-eight pattern which is minimum broadside to the loop. The horizontal loop antenna is omnidirectional (nondirectional) horizontally. Its vertical radiation is predominantly at low angles but is a function of height above ground.

The quarter-wavelength vertical Marconi antenna is omnidirectional horizontally (Fig. 10-20A). Its vertical radiation is predominantly at lower angles, producing a doughnut-like pattern (Fig. 10-20B).

474. Draw a complete schematic diagram of a system of inductive coupling between the output of a radio-frequency amplifier and an antenna system.—See Fig. 10-21.

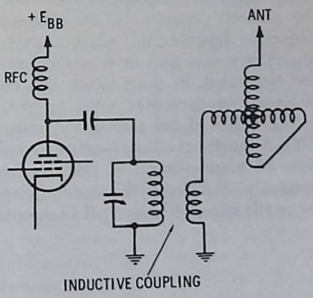


Fig. 10-21. Inductive output coupling.

475. What effect on the plate current of the final amplifier stage will be observed as the antenna circuit is brought into resonance?—The plate current rises because the resonant antenna places maximum load on the output.

476. What is the result of excessive coupling between the antenna and output

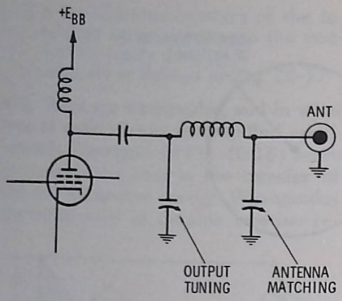


Fig. 10-22. Pi-network matching.

circuits of the self-excited type of vacuum-tube transmitter?—Excessive coupling can be so severe as to stop the circuit from oscillating, the output falling to zero. Excessive coupling usually results in frequency instability, erratic operation, and, at times, excessive plate dissipation.

477. How is the degree of coupling varied in a pi network used to transfer energy from a vacuum-tube plate circuit to an antenna?—Refer to Fig. 10-22. The degree of coupling is adjusted with the output capacitor. The plate-circuit capacitor handles the plate-circuit tuning. There is some interaction between the two, and, in most cases, the degree of coupling increases with an increase in the value of the output capacitor.

478. A master-oscillator–power-amplifier type of transmitter has been operating normally. Suddenly the antenna ammeter reads zero, although all filaments are burning and plate and grid meters are indicating normal voltages and currents. What would be the possible cause(s)?—Defective metering circuit.

479. What is the relationship between the antenna current and radiated power of an antenna?—The radiated power increases as the square of the antenna current ($P = I_A^2R_A$).

480. If the power of a 500-kHz transmitter is increased from 150 watts to 300 watts, what would be the percentage change in field intensity?—Field intensity (microvolt per meter) varies as the square root of the power. If the power doubles, the field intensity rises as $\sqrt{2}$, or by a factor of 1.414. This represents a field-intensity increase of 3 dB.

481. If a 500-kHz transmitter of constant power produces a field strength of 100 microvolts per meter at a distance of 100 miles from the transmitter, what would be the theoretical field strength at a distance of 200 miles from the transmitter?—To an approximation, field strength decreases directly with distance, resulting in a level of 50 microvolts per meter at 200 miles. (In practice, the decline is somewhat faster, and the signal is likely to be somewhat less than 50 microvolts per meter.)

482. If the antenna current at a 500-kHz transmitter is reduced 50%, what would be the percentage change in the field intensity at the receiving point?—The field intensity would be proportional to the antenna current, and there would be a like 50% decrease in field intensity.

CHAPTER 11

Modulation and Test Equipment, Element 6

AUDIO EQUIPMENT

483. List four ways in which an emf may be generated by sound waves.—These are by using sound waves to vary the resistance of a current path, sound pressure on a piezoelectric crystal, sound pressure to produce a variation in capacitance, and the motion of a coil or ribbon in a magnetic field.

484. Draw a diagram of a circuit of a single-button carbon microphone including the microphone transformer and source of power.—See Fig. 11-1. In a single-button carbon microphone, the changes in sound pressure vary the resistance of the carbon granules in their container. These carbon granules are in a dc current path and produce a changing current that follows the sound variations.

485. What are the advantages of the single-button carbon microphone?—Advantages are high sensitivity, economy, and high output.

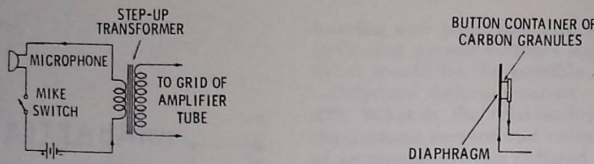
486. What precautions should be observed in the use of a double-button carbon microphone?—To make effective use of a double-button microphone, it must be connected into a balanced circuit (Fig. 11-2) to equalize the button currents. Carbon microphones are subject to granule sticking, which reduces the output and frequency response. This can be caused by rough handling and excessive sound level.

487. What precautions should be observed when using and storing crystal microphones?—It is advisable to store a crystal microphone in a cool, dry location because of its susceptibility to environmental extremes, in particular, to high temperature and high humidity. Rough handling can also damage the crystal, and above all the crystal microphone should not be dropped.

488. What types of microphones have a high-impedance output?—High-impedance microphones are crystal, condenser, and high-impedance velocity types. If a high impedance is desired from a basically low-impedance microphone, a step-up transformer can be used.

489. Draw a circuit diagram showing how a microphone can be connected to an audio amplifier.—See Fig. 11-3.

490. Why is a speech amplifier used in connection with the modulator of a radiotelephone transmitter?—The audio signal level at the output of a microphone is low. A speech amplifier increases this sound level before the audio variations are applied to the modulator of the radiotelephone transmitter.



(A) Circuit diagram. (B) Basic construction.

Fig. 11-1. Carbon microphone.

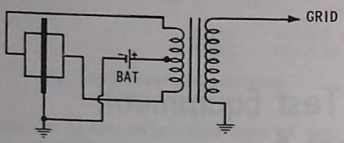


Fig. 11-2. Circuit for double-button microphone.

MODULATION

491. What is the meaning of high-level modulation?—The term "high-level modulation" refers to the modulation of the radio-frequency wave developed in the output circuit (plate circuit) of the final rf power amplifier of the transmitter.

A typical plate-modulated rf amplifier is shown in Fig. 11-4. The modulated amplifier is biased class-C by the self-bias grid combination R1-C1. Audio-modulator tubes V2 and V3 are driven by a signal from the speech amplifier. Transformer T1 provides a suitable match into the modulator. The audio modulation across the secondary of output transformer T2 (usually called a modulation transformer) places an audio variation on the plate-supply voltage to the modulated amplifier.

For example, the supply voltage to the modulated amplifier may be 600 volts. The voltage variation across the secondary of transformer T2 may have a peak amplitude of 600 volts. Therefore, the supply voltage for the modulated amplifier would vary between 0 and 1200 volts, following the audio variation at the output of the modulator. Let us consider how this influences the operation of the modulated amplifier.

In a class-C amplifier, the plate current occurs in bursts, as shown in Fig. 11-5. The peak amplitude of these bursts of plate current depends on the screen-grid and plate voltages. When the screen-grid and plate voltages are maximum (positive peak of modulating wave), the plate-current bursts also have a maximum peak amplitude. When the screen-grid and plate voltage dip to a low value (negative peak of modulating wave across the secondary of the modulation transformer), the plate-cur-

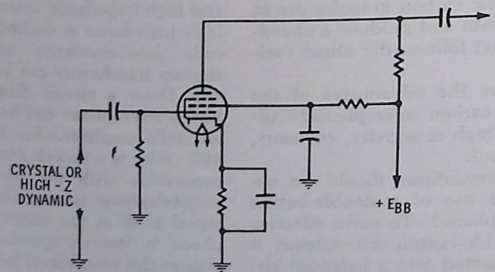


Fig. 11-3. Preamplifier and input circuit for high-impedance microphone.

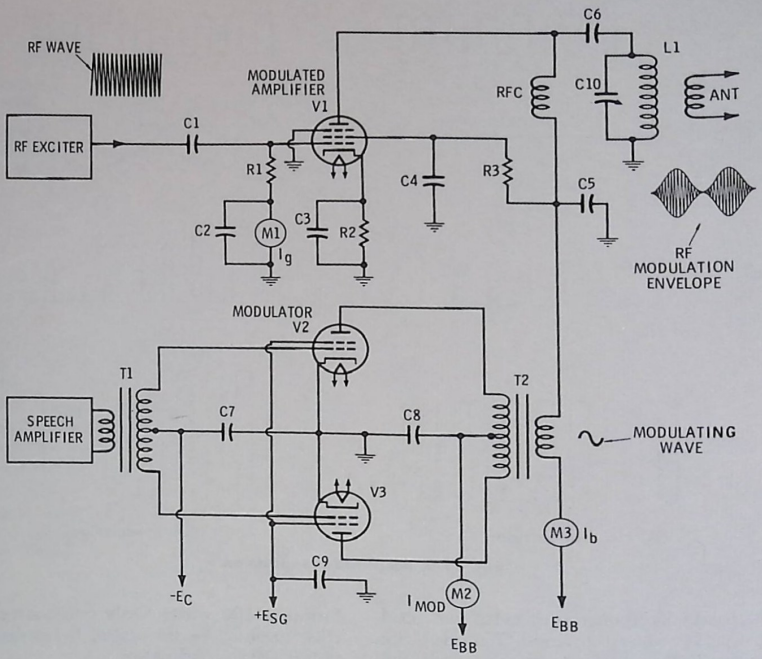


Fig. 11-4. High-level modulation.

rent bursts are minimum in amplitude. It is apparent that the peak amplitude of the plate-current bursts varies with the modulation.

It is these bursts of plate current that charge the resonant tank capacitor to its maximum negative value. The energy-storing ability (flywheel effect) of the resonant tank circuit reconstructs an rf sine wave. The peak amplitude of the plate current determines the amplitude of this rf sine wave.

When there is modulation across the secondary of the output transformer, there is a like variation in the peak amplitude of the plate current. This, in turn, determines just how far negative the tank-circuit capacitor is charged. Of course, the charge placed on the capacitor determines the amplitude of the sine wave that is reconstructed in the tank circuit. It follows, then, that the amplitude of the rf sine waves as they develop in the tank circuit follows the variations in the peak plate current and, in turn, the audio variations present across the secondary of the modulation transformer. Refer again to the waveforms of Fig. 11-5.

When the audio variations at the output of the modulator are of a lower amplitude, there is a reduced peak plate-current variation. Consequently, there is a smaller variation in the peak amplitude of the rf cycles developed across the output tank circuit. In this manner, the rf variations developed across the output of the modulated amplifier follow the changes in the modulating wave.

The output of the modulated amplifier is no longer an rf sine wave of a constant amplitude as it appears at the input of the modulated amplifier. Rather, the sine wave now varies in

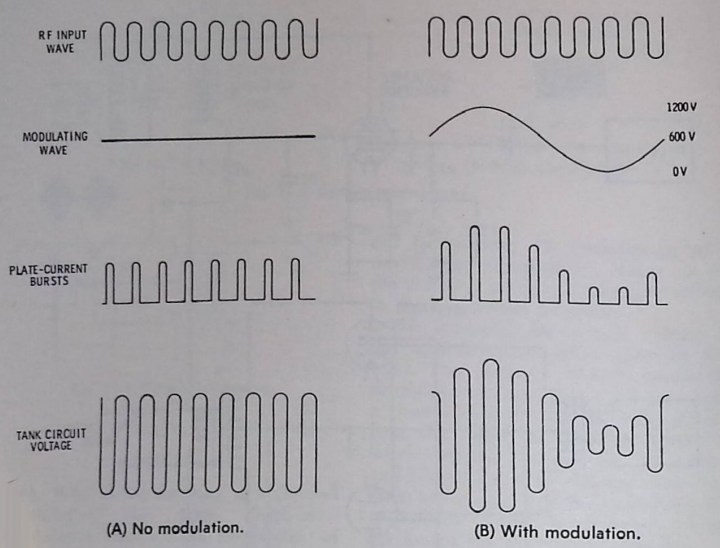


Fig. 11-5. Amplitude modulation.

magnitude in accordance with the modulation. We have formed a modulation envelope. To increase the power level without causing distortion, any following amplifier must operate over the linear portion of its characteristic curve. Thus, the stage that follows the modulated amplifier is not a class-C amplifier; rather, it is operated either in class-AB or class-B. It is said to be a "linear rf amplifier."

492. What is the ratio between the dc power input to the plate circuit of the stage being modulated and the output audio power of the modulator for 100% sinusoidal modulation?—The ratio is 2 to 1. For example, if the dc power input to the plate circuit of the final amplifier of the transmitter is 200 watts, the audio power required for 100% modulation is 100 watts.

493. The dc plate input to a modulated class-C amplifier with an efficiency of 60% is 200 watts. What value of sinusoidal audio power is required to ensure 100% modulation? 50% modulation?—Audio power required for 100% modulation is 100 watts. Only one-quarter of this amount, or 25 watts, is needed to obtain 50% modulation.

494. What increase in antenna current will be observed when a radiotelephone transmitter is modulated 100% by a sinusoidal waveform?—The increase in antenna current will be 22.5%.

495. A ship's transmitter has an antenna current of 8 amperes using A1 emission. What would the antenna current be when this transmitter is 100% modulated by sinusoidal modulation?—The antenna current would be $8 + (8 \times 0.225) = 9.8$ amperes.

496. What is the total bandwidth of a transmitter using A2 emission with a modulation frequency of 800 hertz and a carrier frequency of 500 kHz?—The emission bandwidth is always twice the modulating frequency. In this case, it is $2 \times 800 = 1600$ hertz.

497. If a 1500-kHz radio wave is modulated by a 2000-hertz sine-wave tone, what frequencies are contained in the modulated wave?—The three frequencies contained in the modulated wave

are 1500 kHz, 1502 kHz (1500 + 2), and 1498 kHz (1500 − 2).

498. If a transmitter is adjusted for maximum power output for telegraph operation, why must the plate voltage be reduced if the transmitter is to be amplitude modulated?—The plate voltage must be reduced to permit safe plate dissipation by the modulated stage. Under amplitude modulation, the modulated amplifier does not operate at the same efficiency possible with the amplifier unmodulated. Therefore, the tube plate dissipation increases, and it might become excessive were not the plate voltage reduced.

499. What is indicated in a radiotelephone transmitter by an increase in antenna current without carrier shift?—This is a normal condition. The higher the percentage of modulation, the higher becomes the average antenna current. For 100% modulation, the antenna current increases 22.5% above its unmodulated value.

500. What is a swinging choke?—In general, the inductance of a swinging choke changes inversely with the current. It improves the regulation of a power supply that operates into a widely changing load. A high inductance is obtainable with a low current; yet, the inductance remains sufficient for proper operation under heavy load. The swinging choke is often used in an amplitude-modulation system because of the changing load placed on a power supply by the changing levels of the modulating wave.

501. What is the meaning of carrier shift? What may cause a positive carrier shift in a linear radio-frequency amplifier output?—Carrier shift is caused by a distorted and/or nonsymmetrical modulating wave. Carrier shift can be caused by an actual distortion of the modulating wave present in the modulator or by the inability of the modulated amplifier to follow the maximum amplitude of the modulation peaks. This causes the peaks of the modulated wave to be flattened, causing a negative carrier shift, which is made evident by a dip in modulated-amplifier dc plate current on modulation peaks.

Positive carrier shift is indicated by an increase in the dc plate current of the modulated amplifier with an increase in modulation. This also can be the result of a distorted modulated wave or a defect in the modulated amplifier or succeeding linear rf amplifier. Improper neutralization or the presence of a parasitic oscillation can be a cause. It is evident that what is known as carrier shift is an amplitude change rather than an undesired frequency change.

502. What might be the cause of a positive shift in carrier amplitude during modulation?—Positive carrier shift is most often caused by a distorted modulating wave, inproper neutralization, presence of a parasitic oscillation or improper tuning and loading.

503. Discuss the effect of insufficient radio-frequency excitation on a class-C modulated rf amplifier insofar as the output signal waveform is concerned.—In this condition, the modulation peaks are flattened, resulting in a distorted modulated wave and a negative carrier shift. The output power drops.

504. Under what class of amplification are the vacuum tubes in a linear radio-frequency amplifier stage following a modulated stage operated?—To prevent distortion of the modulation, such stages must be operated class-A or class-B linear. Usually they are operated class-B linear to obtain maximum efficiency and a higher power output.

505. If a class-B linear final radio-frequency amplifier were excited to saturation with no modulation, what would be the effects under modulation?—The modulation envelope would be distorted, the amplifier being unable to follow the modulated variations of the rf envelope. Such a stage would not be able to respond to modulation peaks.

506. If the speech-amplifier tube of a radiotelephone transmitter were overexcited, but the percentage-of-modulation capability of the transmitter were not exceeded, what would be the effect on the output?—The modulated wave would be distorted, because any distortion that occurs prior to the modulation process is not corrected by the modulator and modulated amplifier.

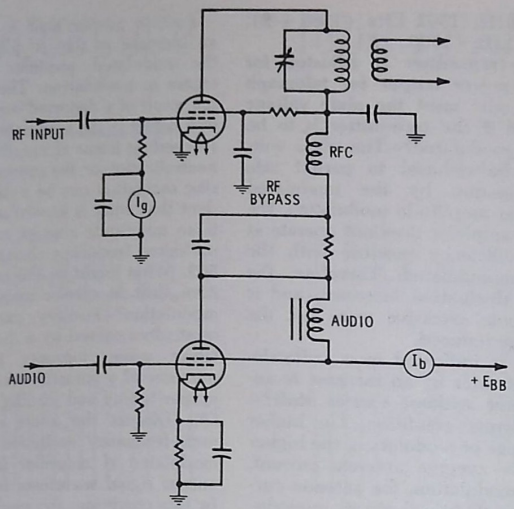


Fig. 11-6. Heising plate modulation.

507. Why is a series resistor used in the dc plate supply of the modulated radio-frequency amplifier, between the amplifier and the modulator, in a Heising modulation system?—A series resistor permits 100% modulation by reducing the dc plate voltage to the modulated amplifier (Fig. 11-6), permitting the modulating wave to swing the instantaneous plate voltage to the modulated amplifier high enough to obtain 100% modulation.

508. What is the purpose of the plate choke used in Heising modulation?—It acts as a modulator load across which the modulating wave is developed. The modulating wave varies the dc plate voltage to the modulated amplifier, producing amplitude modulation.

509. What is meant by low-level modulation?—Low-level modulation occurs in the grid or cathode circuit of the final rf amplifier or in an earlier stage. After modulation occurs, any succeeding radio-frequency amplifier stages must be biased linearly so as not to distort the modulation envelope. The advantage of low-level modulation is that less audio power is required to obtain effective modulation.

510. Compare the characteristics of plate and grid-bias modulation.—Plate modulation requires more audio power than grid-bias modulation for a given amplitude-modulated rf power output. However, plate modulation is more linear and less critical of adjustment. In a plate-modulation system, it is necessary that the plate voltage be varied in accordance with the modulating wave. For grid modulation, it is only necessary to vary the grid voltage over a much more limited range to obtain the same change in plate current. Therefore, much less voltage change and audio power are needed. Thus, in terms of required audio power and economy, grid modulation is preferred over plate modulation.

511. How should the bias of a grid-modulated rf stage be adjusted?—The grid bias must be set at some level (1½ or more times cutoff) to accommodate the modulating wave and maintain a reasonable efficiency. Usually, it is less than that employed for unmodulated operation of the class-C stage.

512. Should the efficiency of a grid-bias–modulated stage be maximum at complete modulation or zero modulation? Explain.—The efficiency varies with the modulation, being highest for maximum modulation. With no modulation, the stage operates at low efficiency. The presence of the modulating wave raises the average efficiency as the instantaneous plate current is made to follow the various peaks of the modulating wave.

513. Is grid current present in the conventional grid-bias–modulated stage of a radiotelephone transmitter under modulated conditions?—Grid current usually does occur during the positive excursions of the modulating wave. Biasing of the modulated stage is usually a combination of self-bias and external bias.

514. Draw a block diagram of an fm transmitter.—Refer to Fig. 11-7. A direct fm system begins with a low frequency oscillator (10 MHz in Fig. 11-7), which is frequency modulated by the modulating wave. The weak microphone signal is first increased in amplitude by a speech amplifier and is then applied to a reactance modulator, a circuit that varies the frequency of the oscillator in accordance with the audio variations. The frequency-modulated output of the oscillator is increased in frequency by a series of multipliers (two doublers and a tripler in Fig. 11-7) up to the transmitting frequency of 120 MHz (12 times 10). The signal is now increased in amplitude and applied to the antenna system. If the 10-MHz oscillator is deviated ±800 Hz by the modulating wave, the final carrier frequency will be deviated by ±9.6 kHz (12 times 800 Hz).

One of the problems with direct frequency modulation is stability of the center frequency. This frequency must be held constant to maintain the assigned value and to avoid distortion. Automatic frequency control is used to maintain a high order of stability. The afc system compares the center frequency of the transmitter through a suitable divider chain to a reference signal generated by a crystal oscillator (Fig. 11-7). A dc error voltage from the afc system is applied to the reactance modulator to correct any drift of the center frequency of the oscillator.

TEST INSTRUMENTS AND MEASUREMENTS

515. What instrument measures electric power?—The wattmeter.

516. What instrument measures electrical energy?—The watt-hour meter.

517. How may the power in an ac circuit be determined?—The wattmeter measures power in an ac circuit. The voltmeter and current meter can also be

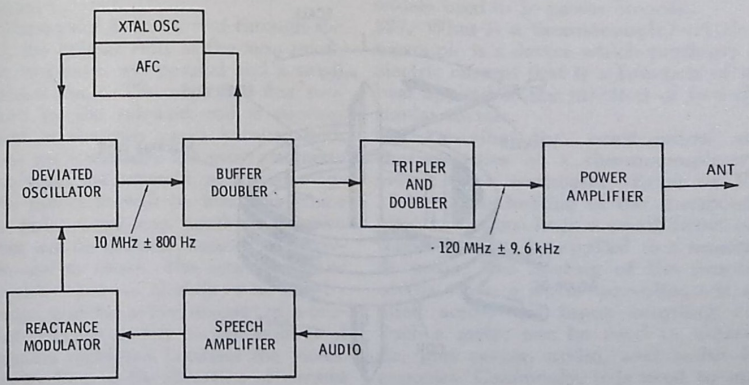


Fig. 11-7. Basic fm system.

used to measure power if the power factor is considered:

$$P = IE \cos \theta$$

518. The product of the readings of an ac voltmeter and ammeter in an ac circuit is called what?—Volt-amperes or apparent power.

519. Does an ac ammeter indicate the peak, average, or effective value of current?—Such a meter reads the effective value.

520. Does the scale of an ac ammeter indicate peak, effective, or average current value? Explain your answer.—The ac ammeter reads the effective value. Although the instrument itself responds to the average current, the scale is usually calibrated in terms of the effective value. However, there is nothing to prevent the use of a suitably calibrated scale for reading average or peak current values.

521. What type of meters may be used to measure radio-frequency currents?—Radio-frequency currents can be measured with thermocouple or hot-wire ammeters.

522. Why are copper-oxide rectifiers associated with dc voltmeters for the purpose of measuring ac not suitable for the measurement of voltages at radio frequencies?—They place a low-impedance load on the source because of their high capacitance.

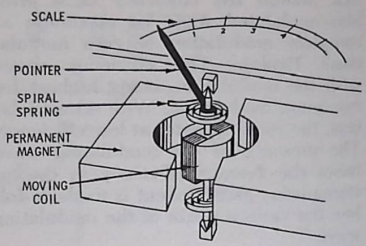


Fig. 11-8. Basic D'Arsonval movement.

523. Describe the construction and characteristics of the D'Arsonval-type meter.—Refer to Fig. 11-8. The D'Arsonval meter contains a fixed permanent magnet and a coil that acts as the movable element within the field of the permanent magnet. An electric current in the coil produces a magnetic field which reacts with the permanent magnetic field. Thus, the coil acts in a manner similar to that of a compass needle and tries to turn until its field lines up with that of the permanent magnet. The turning force that is developed depends on the amount of current in the coil and must overcome the tension of springs arranged to oppose the rotation of the coil. The springs are actually a delicate spring balance, and the ability to overcome its opposition depends upon the

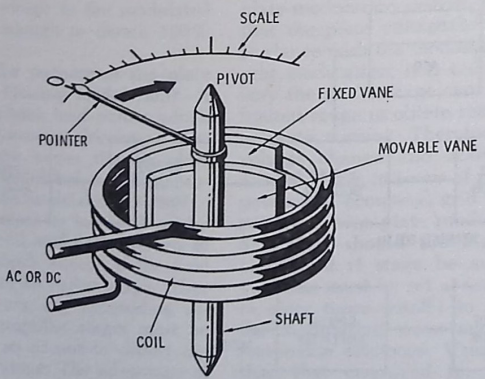


Fig. 11-9. Iron-vane repulsion-type ammeter.

strength of the permanent magnetic field and the field produced by the current in the moving coil.

In a typical D'Arsonval movement, spiral springs at each end of the shaft holding the coil are wound in opposite directions. These springs are coiled and uncoiled by the rotation of the moving parts of the meter. A pointer, attached to the shaft, indicates the amount of rotation on a calibrated scale.

Because the retarding force of the springs is directly proportional to the amount of shaft rotation, the coil will turn just enough to reach a balance between the magnetic forces acting on it and the force applied by the springs. The motion of the pointer attached to the shaft is then directly proportional to the current in the coil.

524. Describe the construction and characteristics of a repulsion-type ammeter.—Refer to Fig. 11-9. The iron-vane repulsion meter uses the principle of repulsion between two like magnetic poles. The movement contains a solenoid, or coil, which is firmly fixed in position. The current that is to be measured is applied to the coil and produces a magnetic field in the solenoid.

Two iron vanes are located in the center of the solenoid. One arrangement of vanes in an iron-vane meter is shown in Fig. 11-9. One vane is mounted in a fixed position, and the other vane is attached to the shaft and moves the pointer.

When there is no current through the coil, the pointer rests at the zero mark. The two vanes are parallel and a small distance apart. The magnetic flux produced by the solenoid coil is concentrated in the two vanes because both vanes get essentially the same magnetic force from the solenoid, and their magnetic polarities will be identical. Since like poles repel one another, the two vanes will do likewise, causing the movable one to rotate. The rotation of the movable vane is slightly retarded by springs, and the actual amount of movement depends mainly on the amount of magnetic repulsion between the vanes.

Regardless of the direction of current in the solenoid, the magnetic polarity always causes the vanes to repel each other, and the indicator or pointer always moves in the same direction. Because of this, the iron-vane instrument can measure current in either direction, which makes it useful as a measuring instrument for alternating current. The inertia of the moving parts prevents the pointer from following the instantaneous changes that take place in the alternating current wave. The movement of the vanes conforms to the effective value of alternating current in the solenoid.

525. Is the angular scale deflection of a repulsion iron-vane ammeter proportional to the square or square root of the current or nearly directly proportional to the current?—The amount of movement is proportional to the square of the current.

526. Describe the construction and characteristics of a dynamometer-type indicating instrument.—Refer to Fig. 11-10. The basic plan of the dynamometer is similar to the D'Arsonval movement with the permanent magnet replaced by two series fixed coils. The current to be measured is passed through the fixed coils as well as the moving coil. The magnetic reaction between the fixed and moving coils causes the moving coil to move the pointer along a calibrated scale. The moving coil is returned to the zero position by a spring when the current is removed. The dynamometer can be used to measure ac or dc and is widely used in ac power circuits.

527. What is a thermocouple?—A thermocouple is a device which produces an electric current that is a function of the heat applied to the junction of two dissimilar metals.

528. Describe the construction and characteristics of a thermocouple-type meter. Of a wattmeter.—Refer to Fig. 11-11A. The heating of the thermocouple junction results in a small direct current which can be applied to a sensitive dc meter. The heating of the junction occurs when a dc or ac voltage is applied across the input coupling coil. Such a meter can be used to measure dc, plus power, audio, and radio frequencies. Commonly, it is used to measure transmitter antenna current.

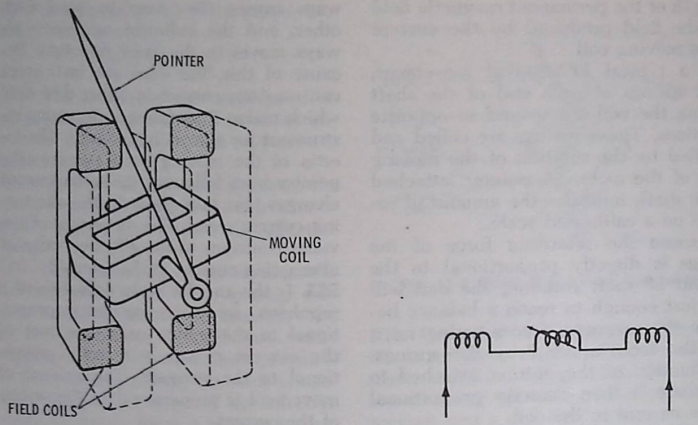


Fig. 11-10. Dynamometer movement.

The wattmeter evaluates both current and voltage. There are two fixed coils and one moving coil (Fig. 11-11B) properly connected to respond to current demand and source voltage. It is a basic dynamometer movement with the two fixed field coils connected in series with the line and the moving coil connected in parallel with the source. A series resistor acts as a voltage multiplier. An increase in current raises the charge motion in the fixed coils, deflecting the moving coil and its pointer. Similarly, an increase in voltage passes more current through the moving coil, resulting in a greater magnetic opposition and additional deflection of the moving coil and its pointer. A wattmeter of this type reads the true power in a circuit. A separate series ammeter and parallel voltmeter produce a product that corresponds to the apparent power.

529. How may the range of a thermocouple ammeter be increased?—Commonly, a current transformer is used to increase the range.

530. Draw a simple circuit diagram showing the principle of operation of an

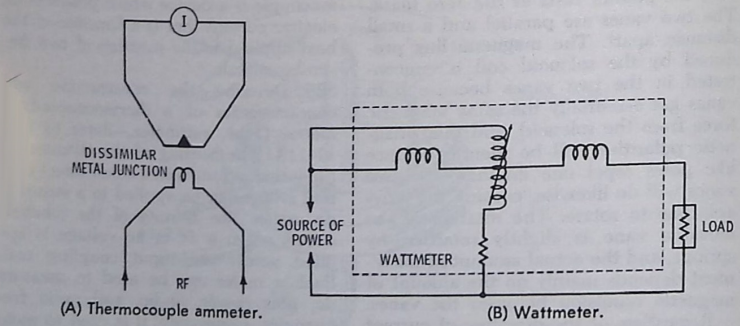


Fig. 11-11. Principles of thermocouple ammeter and wattmeter.

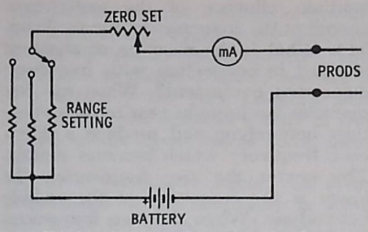


Fig. 11-12. Basic ohmmeter circuit.

ohmmeter.—Refer to Fig. 11-12. The basic ohmmeter consists of a series-connected battery, current meter, and zero-adjust resistor and control. When the terminals are shorted, the zero-adjust resistance is set to produce a zero ohms reading. The short is removed, and the resistance to be measured is connected across the terminals. The current reading will now drop according to the value of the unknown resistance. The meter scale is calibrated to read resistance rather than current. Various resistance scales can be set up by using various combinations of calibrated precision resistors in the ohmmeter circuit. These can be switched in and out in accordance with the desired resistance scales.

531. What is the purpose of a multiplier resistor used with a voltmeter?—Such a series multiplier resistor increases the range of voltage that can be measured by the voltmeter.

532. What is the purpose of a shunt as used with an ammeter?—Such a shunt resistor increases the current range that can be measured with the ammeter.

533. If two ammeters are connected in series, how may the total current through the two meters be determined?

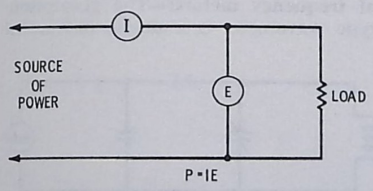


Fig. 11-13. Measurement of dc power with voltmeter and ammeter.

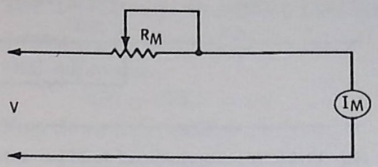


Fig. 11-14. Use of milliammeter to measure voltage.

—In a series circuit, the same current is present throughout. Therefore, each meter will read the total current.

534. If two ammeters are connected in parallel, how may the total current through the two meters be determined?—Assuming the two ammeters are identical, each meter will read one-half of the total current. Therefore, the total current will be the sum of the two readings.

535. If two voltmeters are connected in series, how would you be able to determine the total drop across the instruments?—Assuming the two meters are identical, the total drop would be the sum of the identical readings on the two voltmeters.

536. Show by a diagram how a voltmeter and ammeter should be connected to measure power in a dc circuit.—See Fig. 11-13.

537. How may a dc milliammeter be used in an emergency to indicate voltage?—This can be accomplished with the use of a series multiplier resistor (Fig. 11-14). The resistor can be adjusted until the current reading is maximum or some desired reference reading. Ohm's law is then used to determine the voltage:

$$\text{Voltage} = I_M R_M$$

538. Indicate by a diagram how the total current in three branches of a parallel circuit can be measured by one ammeter.—Refer to Fig. 11-15. Note that the meter is inserted in the common path between the voltage source and the three parallel branches.

539. A milliammeter with a full-scale deflection of 1 mA and having an internal resistance of 25 ohms is used to measure an unknown current by shunt-

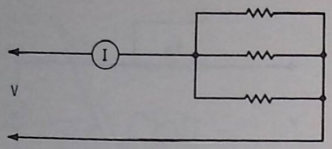


Fig. 11-15. Measurement of total current.

ing it with a 4-ohm resistance. When the meter reads 0.4 milliampere, what is the actual value of the current?—By proportion:

$$\frac{R_M}{R_S} = \frac{I_S}{I_M}$$

$$I_S = I_M \left(\frac{R_M}{R_S}\right) = 0.4 \times \frac{25}{4} = 2.5 \text{ mA}$$

$$I_T = I_M + I_S = 0.4 + 2.5 = 2.9 \text{ mA}$$

540. If a dc voltmeter is used to measure effective alternating voltages by the use of a bridge-type full-wave rectifier of negligible resistance, by what factor must the meter readings be multiplied in order to give corrected readings?—Since a dc meter responds to average voltage ($0.636 \times E_{PEAK}$) and the effective voltage ($0.707 \times E_{PEAK}$) is wanted, the following ratio must be used:

$$\text{Ratio} = \frac{0.707}{0.636} = 1.11$$

541. By what factor must the voltage of an ac circuit, as indicated on the scale of an ac voltmeter, be multiplied in order to obtain the peak value?—Since the ac voltmeter scale reads rms value, the reading must be multiplied by the ratio 1/0.707, or 1.414.

542. By what factor must the voltage of an ac circuit, as indicated on the scale of an ac voltmeter, be multiplied in order to obtain the average voltage value?—A multiplier factor of 0.9 is required:

$$\text{Ratio} = \frac{0.636\, I_{PEAK}}{0.707\, I_{PEAK}} = 0.9$$

543. What precautions should be used when an absorption-type frequency meter is used to measure the output of a self-excited oscillator?—Employ very loose coupling between the oscillator and the frequency meter to prevent the loading influence of the meter from changing the frequency of the oscillator.

544. What is the meaning of zero-beat as used in connection with frequency-measuring equipment?—When two frequencies are brought near to each other, they heterodyne and produce a difference frequency which becomes audible. The nearer the two frequencies, the lower is the frequency of the audible heterodyne. When the two frequencies are identical, the difference frequency is zero, and it is customary to state that a zero beat has been reached. As one frequency is varied on either side of the zero-beat position, there will be an increase in the audio difference frequency. Therefore, as one frequency is tuned across the other, the tone of the difference frequency first decreases from a high-pitched note to a low one and finally to zero. If the frequency change is continued in the same direction, the difference frequency will be audible again, starting at a low frequency and continuing up to a higher frequency.

545. What precautions should be taken before using a heterodyne type of frequency meter?—The meter should be allowed to warm up and then should be calibrated according to the instructions that accompany it. When the source of signal is very weak and direct coupling must be used between the signal source and the frequency meter, be certain any such interconnections do not put any sort of load on the signal source that would shift its frequency.

546. Draw a simple schematic diagram of an absorption-type wavemeter.—See Fig. 11-16.

547. What are the advantages and disadvantages of using an absorption-type wavemeter in comparison to other types of frequency meters?—The absorption-type wavemeter is a simple instrument

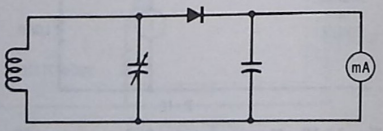


Fig. 11-16. Absorption wavemeter.

that does not require a source of power. It is limited with regard to the accuracy of the frequency measurement, and sometimes to obtain a usable reading it is necessary to use tight coupling that may or may not result in a shift in frequency of the signal source being measured.

548. If a wavemeter having an error proportional to the frequency is accurate to 20 Hz when set at 1000 kHz, what is its error when it is set at 1250 kHz?—Assuming the same percentage of error, the accuracy at the new frequency is calculated by proportion:

$$\frac{0.20}{1000} = \frac{x}{1250}$$

$$x = 25 \text{ Hz}$$

549. An absorption-type wavemeter indicates that the approximate frequency of the ship transmitter is 500 kHz, and at the same time the transmitter signal produces a zero beat on an accurately calibrated heterodyne frequency meter at a dial reading of 374.1. The frequency-meter calibration book indicates dial readings of 367.0, 371.5, and 376.0 for frequencies of 499.4/998.8, 499.6/999.2, and 499.8/999.6 kilohertz, respectively. What is the frequency of the ship's transmitter?—The absorption wavemeter indicates that the frequency is somewhere in the vicinity of 500 kHz. The frequency-meter readings can now be used to determine the exact frequency:

Calibration differences:

Dial—(376 — 371.5 = 4.5)
Freq—(499.8 — 499.6 = 0.2)

This corresponds to 0.0444 kHz per division $\left(\frac{0.2}{4.5}\right)$.

Dial difference:

$$376 - 374.1 = 1.9$$

Freq down from calibration point:

$$1.9 \times 0.0444 = 0.08436$$

Operating frequency:

$$499.8 - 0.08436 = 499.7156 \text{ kHz}$$

550. A certain frequency meter contains a crystal oscillator, a variable oscillator, and a detector. What is the purpose of each of these stages in the frequency meter?—The purpose of the detector is to obtain a useful zero beat when a known signal frequency and an unknown signal frequency are applied to its input. The variable oscillator and its associated calibrated scale provide the known-frequency signal. Therefore, when it is tuned to the same frequency as the unknown signal, the frequency-meter reading will be that of the unknown signal.

It is important that the variable-oscillator frequency calibration be exact. For this purpose, a fixed-frequency crystal oscillator is included. It is used to calibrate the frequency of the variable oscillator. The detector is employed also to obtain a zero beat between the crystal-oscillator signal and the variable-oscillator signal.

551. With measuring equipment that is widely available, is it possible to measure a frequency of 10 MHz to within 1 hertz of the exact frequency?—No. Such a measurement would require an accuracy of 1 part in 10 million. Such equipment is not widely available.

CHAPTER 12

Receiver Circuits, Element 6

DETECTORS

552. Draw a simple schematic diagram of a diode vacuum tube connected for diode detection, and show a method of coupling to an audio amplifier.—See Fig. 12-1.

553. Explain the operation of a diode type of detector.—A diode detector is a combination rectifier and filter. Its rectifier action permits conduction during one alternation of an applied modulation envelope (Fig. 12-1). A unidirectional instantaneous current follows the variation of the radio-frequency peaks. Hence, the diode current is a replica of the modulation present on the incoming radio-frequency envelope. The output network acts as an rf filter but does not filter out the modulating signal. As a result, the original modulation is recovered at the output of the diode detector.

554. Draw a circuit diagram of a crystal-detector receiver, and explain its principle of operation. Name two substances that can be used as the crystal in such a receiver.—Refer to Fig. 12-2. A crystal detector is also a diode, and its general operation is the same as for the diode detector of Fig. 12-1. However, no filament is required. Modern crystal detectors are made of silicon, with two sections of opposite charge (p and n types). The basic operation of such a semiconductor diode was covered in question 161. Galena crystal is also used widely in crystal detectors. For this type of detector, a tiny point contact is made between a metal conductor and the crystal. This type of construction also acts as a unidirectional device, and it is possible to demodulate an incoming amplitude-modulated wave.

In the circuit (Fig. 12-2), the inductor-capacitor combination makes the input sensitive to a particular radio frequency. The incoming modulation envelope causes the crystal current to charge the filter capacitor in accordance with the variations of the envelope peaks. This demodulated audio is applied to the headset.

555. Name four materials which can be used as crystal detectors.—Four such materials are silicon, galena, carborundum, and iron pyrites.

556. Draw a simple schematic diagram of a triode vacuum tube connected for grid-leak detection.—See Fig. 12-3.

557. Explain the operation of a grid-leak detector.—The grid-to-cathode circuit of a grid-leak detector functions like a diode detector, the grid serving as the plate of the diode operation (refer to question 552). However, an amplified version of the demodulated signal at the grid is developed in the plate output circuit.

The grid-leak detector is biased near saturation by the grid current drawn during the positive crest of the rf cycles of the applied modulation envelope. The

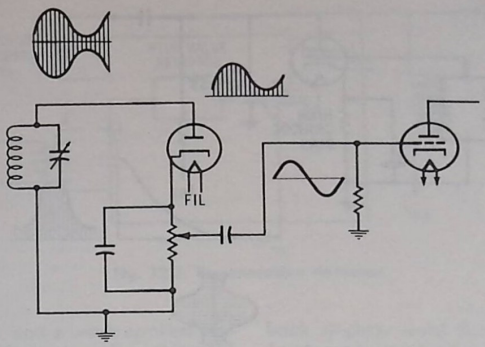


Fig. 12-1. Diode detector coupled to audio amplifier.

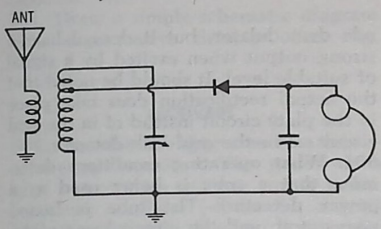


Fig. 12-2. Crystal receiver.

negative alternations of the applied modulation envelope swing down over the linear portion of the tube transfer characteristic, as shown in Fig. 12-3. The instantaneous plate current follows the variations of the negative rf peaks, and these variations produce an amplified version of the grid-signal change in the output. The rf cycles are filtered out by the output capacitor.

The grid-leak detector is sensitive and develops a reasonably strong output. It

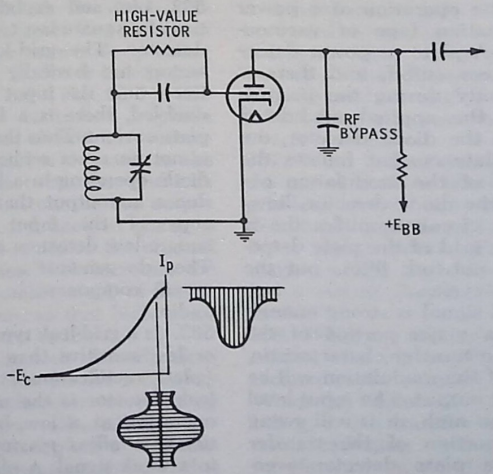


Fig. 12-3. Grid-leak detector.

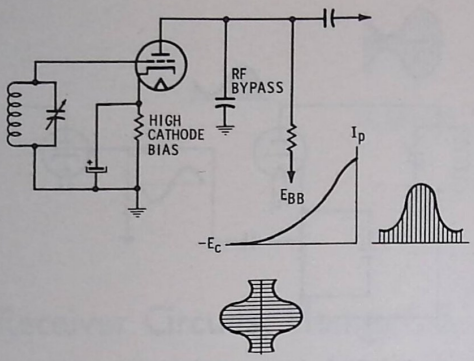


Fig. 12-4. Plate detector.

must not be overloaded by too strong a signal; otherwise, a reasonably undistorted output cannot be developed.

558. What effect does an incoming signal have on the plate current of a triode detector of the grid-leak type?—The stronger the incoming signal (modulated carrier), the more the plate current will decrease in a grid-leak detector.

559. Draw a simple schematic diagram of a triode detector tube connected for plate or power detection.—See Fig. 12.4.

560. Explain the operation of a power or plate-rectification type of vacuum-tube detector.—A plate or power detector is biased near cutoff, and there is plate current only during the positive alternations of the applied modulated rf signal. As in the diode detector, the instantaneous plate current follows the peak variations of the modulation envelope. Unlike the diode detector, however, the triode circuit amplifies the rf variations at the grid of the plate detector. An output network filters out the radio-frequency cycles.

If the applied signal is strong enough to swing over a major portion of the linear part of the transfer characteristic, a good replica of the modulation will be developed in the output. The input level should not be too high, or it will swing off the linear portion of the transfer curve. Thus the plate detector overloads easily in comparison with the diode demodulator, but it does deliver a strong output when excited by a signal of suitable level. It should be noted that the actual rectification does take place in the plate circuit instead of in the grid circuit as in the grid-leak detector.

561. What operating conditions determine that a tube is being used as a power detector?—The tube is biased near cutoff, and the circuit has a plate-circuit rf filter and a high-Q, high-resistance grid circuit.

562. List and explain the characteristics of a square-law type of vacuum-tube detector.—The grid-leak and plate detectors are basically square-law types. Each time the input voltage change is doubled, there is a fourfold change in plate current. Thus the output waveform is not an exact replica of the input. A diode operating in a linear manner produces an output that is a more exact copy of the input wave. However, square-law detectors are more sensitive. They do generate a strong second-harmonic component in the demodulated audio.

563. Is a grid-leak type of detector more or less sensitive than a power detector (plate rectification)? Why?—The grid-leak detector is the more sensitive. By operating at a low bias (near saturation), it offers maximum amplification to a weak signal. A plate detector operates near cutoff, where the mutual con-

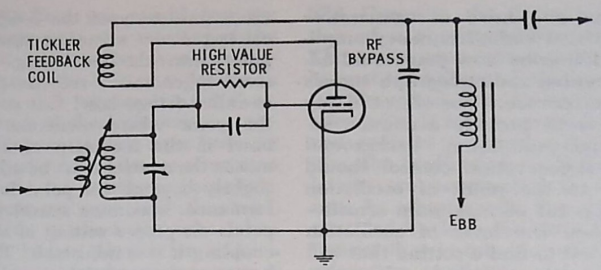


Fig. 12-5. Regenerative detector.

ductance is low, and a weak applied signal is not amplified as much as it would be at a point higher on the transfer characteristic.

564. Draw a simple schematic diagram of a regenerative detector.—See Fig. 12-5.

RECEIVERS

565. Describe the operation of a regenerative-type receiver.—The major units of a regenerative receiver are a radio-frequency amplifier (optional), a grid-leak detector with feedback, an audio amplifier, and a power source. The rf amplifier, audio amplifier, and power source are conventional. The demodulator is a grid-leak detector that functions as described in the answer to question 556, except that a feedback link is provided by a tickler coil (Fig. 12-5). The circuit supplies a controlled in-phase feedback to the grid circuit. The incoming modulated signal is detected in the conventional manner by the grid-leak detector. However, some of the output of the detector is fed back in phase to the grid circuit to reinforce the original grid signal. This feedback increases the impedance and the effective Q of the input resonant circuit, so that high sensitivity and selectivity result.

Control of the amount of feedback is usually provided because the sensitivity of a regenerative detector increases up to the point where self-oscillation occurs. Thus, in the reception of a modulated signal, the regeneration control is advanced to this point. It is then turned back slightly until the oscillations cease. In the reception of a cw (code) signal, however, the regeneration control is advanced to the point of oscillation, because oscillations are necessary to recover the interrupted-carrier cw information. This is a heterodyning process. The audible beat note reproduces the original dots and dashes of the code message. An advantage of a regenerative detector over the types described previously is its ability to receive cw A1 signals.

566. In the operation of a regenerative type of receiver, how is oscillation of the detector indicated?—It is indicated by an audible beat note which is heard as a howl or whistle. This whistle can be heard when any type of signal is tuned in. Also, when the regeneration control of the detector is adjusted, an audible swish or thud is heard when the point between nonoscillation and oscillation is crossed.

567. What is the principal advantage in the use of a diode detector instead of a grid-leak triode detector?—The diode detector is capable of handling a strong input signal without distortion, particularly at high modulation levels, and it has a circuit that is simple and easily tuned.

568. What are the objections to the operation of a regenerative oscillating detector directly coupled to an antenna?—When the regenerative detector is oscillating, it can transfer energy to the antenna, radiating a signal that may cause interference on nearby receivers tuned to the same frequency.

569. Assume you have a regenerative receiver without radio-frequency amplifier stages. Describe how you would adjust it to receive radiotelegraph signals through interference.—The object of any adjustment is to provide maximum selectivity and minimum background noise. The regeneration control should be set just to the point of oscillation (this is the point of maximum sensitivity), and then the level of oscillation can be reduced to find a setting that will give a usable desired signal with a minimum of interference. Antenna coupling, too, has a great influence on selectivity and interference level. Maximum selectivity is obtained with loose coupling. However, the degree of loose coupling depends on the desired signal level. Coupling can be reduced to a point that you receive a useful desired signal and minimum interference. The optimum setting of the regeneration control and antenna coupling is important in establishing the very best signal-to-interference ratio.

570. Describe how you could test a regenerative receiver to determine if the detector is in an oscillating condition.—The usual regenerative-detector heterodyne when receiving a signal indicates detector oscillation. Also, a good indicator is the thud or swishing sound that you hear when you adjust the regeneration control to that point between the oscillating and nonoscillating conditions. The oscillating detector can be picked up on a nearby receiver if that receiver is tuned to its frequency. Likewise, a heterodyne frequency meter can be used to check for detector oscillation. The oscillating detector also has a high negative grid bias, and a high-impedance voltmeter can be used to determine if oscillations are present by the abrupt rise in negative bias as the regeneration control is changed between nonoscillating and oscillating conditions.

571. How may a regenerative-type receiver be adjusted for maximum sensitivity?—In the nonoscillating condition, the setting of the regeneration control that results in maximum sensitivity occurs just before the point at which the receiver would go into oscillation. Maximum sensitivity of the receiver for receiving a cw signal is just over that point into the oscillating region. In some regenerative receivers, there is a so-called fringe howl that occurs just at the point where oscillation begins. A howl in the reception of a cw signal means the control must be advanced just slightly beyond this point for best performance. Maximum sensitivity also depends on proper setting of the antenna coupling if it is adjustable. The receiver becomes more sensitive as the coupling is increased. However, when the coupling is too tight, the self-oscillating condition is harmed and may be stopped, producing a sharp drop in sensitivity.

572. Name three causes of an audio howl in a regenerative receiver.—In some receivers, an improper setting of the regeneration control produces howl. Another cause of howl would be a feedback path in the receiver if a multiple-stage audio amplifier is used. Defective filtering- or decoupling-circuit components and open grid circuits can produce howl.

573. If a ship's regenerative receiver failed to oscillate when the regeneration control was advanced, explain the possible causes and remedies.—A failure to oscillate may be the result of low filament voltage, low B-supply voltage, an open tube filament or otherwise failing tube, or a defective component. Replace the tube if faulty, and check the supply voltages with a voltmeter. Inspect the feedback circuit in particular to make certain there are no loose connections or a defective feedback coil. An antenna, if it places too much load on the receiver input, can also cause the regenerative detector to fail to oscillate. In this case, the remedy is to decouple the antenna system to the point at which oscillations can start.

574. What controls determine the selectivity of a three-circuit receiver?—The selectivity is set mainly by the regeneration control. Antenna coupling, too, has an influence on selectivity, and it is sometimes necessary to make a suitable compromise between selectivity and sensitivity.

575. Explain how you would test the various components of a receiver of the three-circuit regenerative type in troubleshooting.—In the case of a decline in performance of a regenerative receiver, the first step is to check the various controls to make certain they have been set properly, particularly the regeneration control and the antenna coupling. Check supply voltages and the tube. The best way to check the tube when you do not have a checker to make a good evaluation of tube performance is by substitution. Check all terminals for proper connection, voltage, and tightness. The coil of the three-circuit transformer can be tested for continuity. Inspect and test any switching. If no fault has been found, then the individual components should be inspected and tested.

576. What may be the cause of noisy operation of a regenerative three-circuit receiver having two stages of audio-frequency amplification?—Noisy operation can often be traced to controls and loose connections. Check the regeneration and volume controls. Check the antenna, ground, and supply-voltage connections. Make certain the tube is not defective and it is seated properly in its socket. A leaky grid capacitor and other coupling capacitors can be a source of noise. A microphonic audio input tube could be the cause.

577. Discuss the relative advantages and disadvantages of a stage of radio-frequency amplification for use in connection with a regenerative receiver.—Radio-frequency amplification can be used to improve the sensitivity and selectivity of the receiver and increases the signal-to-noise ratio. Additional audio amplification just increases the level of signal that is demodulated by the detector without having any influence on the sensitivity or selectivity of the receiver. A radio-frequency stage also isolates the oscillating detector from the antenna and prevents the radiation of oscillations which can cause interference to other receivers. Such an rf amplifier requires additional parts and tuning controls. Shielding is needed and possibly neutralization.

578. Describe the principle of operation of a superregenerative receiver.—The superregenerative detector has the highest sensitivity of the various detectors described, but it also has very poor selectivity. It is also an oscillating circuit and radiates a broad signal. In operation, the feedback is such that the oscillations are interrupted at a supersonic rate. In other words, the signal component fed back to the grid is an rf component that is interrupted by a second, relaxation oscillation. In this way, the receiver is held continuously at its most sensitive level. An incoming weak signal suppresses the high background noise that is characteristic of this type of detection when no signal is being received. However, the output signal produced by an incoming weak carrier reaches almost the level that would be derived from a strong input signal.

579. Why should polarity be observed in connecting head telephones directly in the plate circuit of a vacuum tube?—Some older magnetic headphones are polarized in that the best reproduction is obtained when the magnetic fields of the permanent magnet and electromagnet are aiding.

580. Why do headphone receivers used in radiocommunication usually have high-impedance windings? — High-impedance windings permit direct connection to the high impedance of the plate outputs of audio amplifiers. Thus, a matching transformer is not required.

581. If low-impedance head telephones of the order of 75 ohms are to be connected to the output of a vacuum-tube amplifier, how may this be done to permit satisfactory operation?—An output transformer should be used to match the low impedance of the headset to the high impedance of the plate output circuit of the vacuum-tube amplifier.

582. What is the main advantage of a tuned audio-frequency amplifier in a receiver used for the reception of radiotelegraph signals?—Such a tuned audio system improves the signal-to-interference and signal-to-noise ratios. Since a radiotelegraph signal has a very narrow bandwidth, such a sharply tuned audio system can be employed. It reduces in-

terference from signals on adjacent frequencies that ordinarily might produce high-frequency heterodyne interference.

583. If signals are heard with the headphones plugged into the detector plate circuit of the receiver, but no signals are heard when the headphones are plugged into the plate circuit of the first audio-frequency amplifier, what might be the cause, and how could it be remedied?—This step isolates the trouble to the audio stage or its input or output circuit. A temporary solution might be to connect the output of the detector directly to the input of the succeeding audio stage, leaving the first audio amplifier out of the circuit. Check the first audio tube by substitution, and then its supply voltages. A defective coupling circuit (including a defective audio transformer, if used) may cause the loss.

584. Give four conditions which would prevent a regenerative receiver from oscillating.—Improper adjustment of regeneration control, too tight antenna coupling, failing tube, or low filament voltage. Refer to question 573.

585. What might be the cause of low sensitivity of a three-circuit regenerative receiver?—Low sensitivity might be the result of too loose antenna coupling or improper setting of the regeneration control. There may be an actual circuit or component defect. The first step is to check the tube and the supply voltages to the receiver. Refer to question 575.

586. What effects might be caused by a shorted grid capacitor in a three-circuit regenerative receiver?—Such a receiver would not function as an oscillating detector, and there would be no effective regeneration. No signal or only a very strong signal could be received.

TRF RECEIVERS

587. Draw a simple schematic diagram showing a method of inductive or transformer coupling between two stages of a radio-frequency amplifier.—A two-stage radio-frequency amplifier is shown in Fig. 12-6. Multigrid tubes are used almost exclusively for radio-frequency amplifiers because they do not require neutralization. Tuned transformers are used widely, particularly between stages. Quite often, when the antenna is connected to the input stage, the primary may be untuned. In this case, a low-impedance winding is used for the primary to match the antenna system properly. It is these tuned resonant circuits and transformers that set the selectivity of a tuned radio-frequency amplifier. The input stage is usually a low-noise design, and the associated receiver will then have both high selectivity and high sensitivity (high signal-to-noise ratio). The biasing of the rf stages is usually handled by a cathode resistor-capacitor combination. Plate-circuit decoupling resistor-capacitor combinations are also used to establish proper operating voltages as well as to reduce the tendency to motorboating and feedback instability. Screen-circuit resistor-capacitor combinations are used to develop the proper screen voltage and to keep the screen voltage constant so as not to result in signal degeneration.

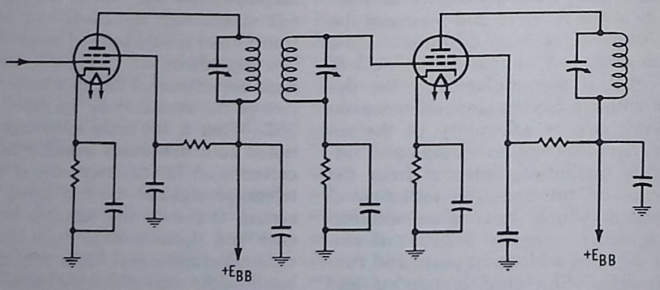


Fig. 12-6. Transformer coupling between rf stages.

588. What is meant by split tuning?—When the primary and secondary resonant circuits of a double-tuned rf transformer are coupled too tightly, a double-humped response curve is obtained instead of a sharp single-peak curve. This results in a drop in selectivity and a so-called "split-tuned response."

589. Why are bypass capacitors used across the cathode bias resistors of a radio-frequency amplifier?—These capacitors hold the cathode bias constant and prevent the cathode current variations from developing a feedback voltage across the cathode resistor. Such a feedback voltage would be out of phase with the grid signal and would cause loss of amplifier gain.

590. Draw a simple schematic diagram showing a method of impedance coupling between two stages of a radio-frequency amplifier.—See Fig. 12-7.

591. Does a pentode vacuum tube usually require neutralization when used as a radio-frequency amplifier?—No. This is the reason the multigrid tube is popular as both a radio-frequency amplifier in receivers and a radio-frequency power amplifier in transmitters.

592. What is the purpose of an electrostatic shield?—An electrostatic, or Faraday shield, minimizes the transfer of harmonic frequencies between inductively coupled circuits. This transfer takes place through an undesired capacitive path between the two coils of the transformer. The blocking of this path is the major function of the electrostatic shield in a transmitter. Sometimes such shields are used in receiver circuits to block the transfer of very strong local signals that may occur on frequencies far removed from the signal frequencies to which the receiver tuned transformers are resonant.

593. Draw a simple schematic diagram showing a method of coupling between two tetrode vacuum tubes in a tuned radio-frequency amplifier. — See Fig. 12-6.

594. Draw a simple schematic diagram showing a method of coupling between two triode vacuum tubes in a tuned radio-frequency amplifier and a method of neutralization to prevent oscillation. —See Fig. 12-8.

595. What is the advantage of using iron cores of special construction in radio-frequency transformers and inductances?—These cores greatly improve the efficiency of radio-frequency transformers and inductors. They reduce transformer coupling loss and increase both the Q and selectivity. All these advantages can then be gained in a compact transformer or coil design. Such cores can be made adjustable, providing a method of tuning.

596. What is the purpose of a center-tapped connection in a filament-supply transformer?—Such a connection reduces hum pickup and in effect improves the signal-to-noise or signal-to-hum ratio of the receiver.

597. Draw a diagram showing a method of obtaining grid bias for a fila-

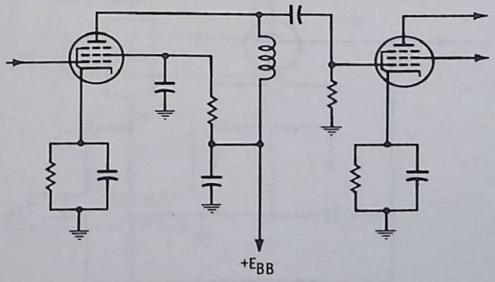


Fig. 12-7. Impedance coupling between rf stages.

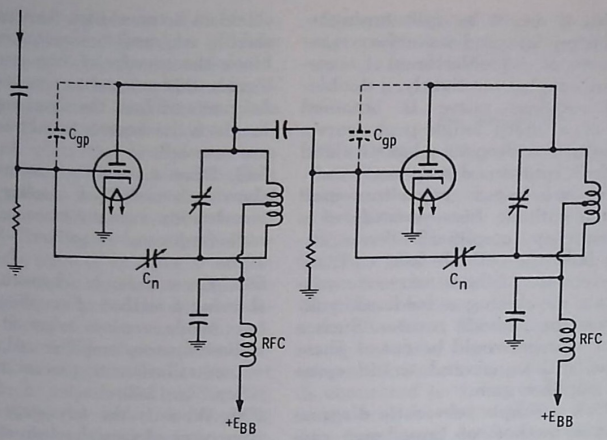


Fig. 12-8. Interstage coupling between plate-neutralized triodes.

ment-type vacuum tube by use of resistance in the plate circuit of the tube.—See Fig. 12-9.

598. Draw a diagram of a tuned-radio-frequency receiver.—See Fig. 12-10.

599. In a tuned-radio-frequency receiver, what is the advantage of heterodyne reception as compared to autodyne reception?—The major advantage is the higher stability and ease of tuning. No regeneration control (and its critical setting) or antenna-coupling adjustment is required. The heterodyne method also permits high sensitivity and ease of adjustment of the audible tone when a cw signal is being receiver.

600. What is the purpose of shielding between radio-frequency amplifier stages?—Shielding between radio-frequency amplifiers blocks undesired signal transfer and prevents feedback oscillation, instability, and other undesired interactions among the stages of a high-gain rf amplifier, whether in a receiver or transmitter.

SUPERHETERODYNE RECEIVERS

601. Draw a block diagram of a superheterodyne receiver capable of receiving continuous-wave (cw) radiotelegraph signals.—See Fig. 12-11.

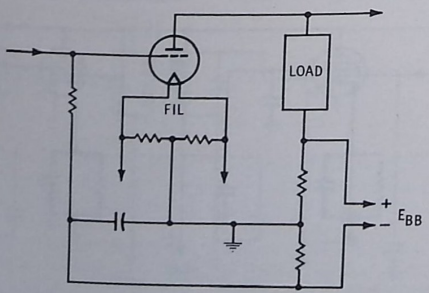


Fig. 12-9. Grid bias from plate-supply bleeder arrangement.

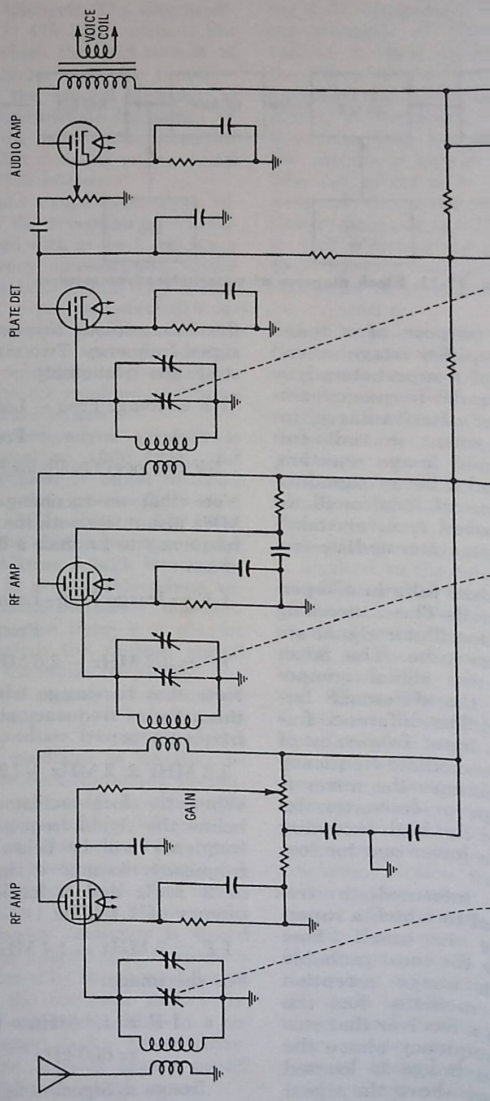


Fig. 12-10. A trf receiver with two tuned rf stage

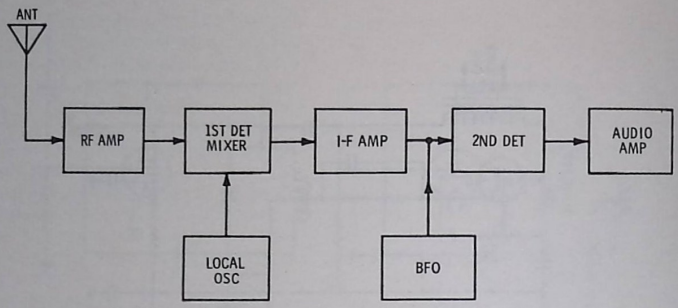


Fig. 12-11. Block diagram of superheterodyne receiver.

602. What is the purpose of a tuned radio-frequency amplifier stage ahead of the mixer stage of a superheterodyne receiver?—Such a radio-frequency amplifier has a number of advantages, including an improvement in radio-frequency selectivity and image rejection, higher sensitivity and a better signal-to-noise ratio, reduction of local-oscillator radiation, and improved receiver stability by requiring less intermediate-frequency gain.

603. What is the mixer tube in a superheterodyne receiver?—The incoming signal and the local-oscillator signal are applied to the mixer tube. The mixer heterodynes these two signal components and recovers the difference frequency in its output. The difference frequency matches the input frequency of the following intermediate-frequency (i-f) amplifier. Sometimes the mixer is called a first detector or converter. Its purpose is to convert the high incoming signal frequency to a lower one for further amplification.

604. Knowing the intermediate frequency and the signal to which a superheterodyne receiver is tuned, how would you determine the most probable frequency on which image reception would occur?—The oscillator has the pivotal frequency. In a receiver that employs an oscillator frequency above the signal frequency, the image is located twice the i-f frequency above the signal frequency. In a receiver with the local-oscillator frequency below the signal frequency, the image frequency is twice the intermediate frequency below the signal frequency. Two examples demonstrate the relationship:

$$\text{I-F} = \text{Image Freq} - \text{Local-Oscillator Freq}$$

$$\text{I-F} = \text{Local-Oscillator Freq}$$

Note that an incoming signal of 3.2 MHz also mixes with the local-oscillator frequency to produce a 600-kHz difference:

$$\text{I-F} = \text{Image Freq} - \text{Local Oscillator Freq}$$

$$\text{IF} = 3.2\ \text{MHz} - 2.6\ \text{MHz} = 600\ \text{kHz}$$

Note that the image frequency is two times the i-f frequency above the signal frequency or:

$$3.2\ \text{MHz} = 2\ \text{MHz} + (2 \times 600\ \text{kHz})$$

When the local-oscillator frequency is below the signal frequency, the image frequency will be below the oscillator frequency. Assume a signal frequency of 2 MHz and a local-oscillator frequency of 1.4 MHz.

$$\text{I-F} - 2\ \text{MHz} - 1.4\ \text{MHz} = 600\ \text{kHz}$$

For the image:

$$\text{I-F} = 1.4\ \text{MHz} - 0.8\ \text{MHz}$$

$$= 600\ \text{kHz}$$

$$\text{Image} = \text{Signal} - 2(\text{I-F})$$

$$\text{Image} = 2\ \text{MHz} - 2(0.6\ \text{MHz})$$

$$= 0.8\ \text{MHz}$$

605. A superheterodyne receiver is adjusted to 2738 kilohertz. The intermediate frequency is 475 kHz; what is the frequency to which the grid circuit of the second detector must be tuned?—The input to the second detector is tuned to the intermediate frequency of 475 kHz. It is the input to the mixer, or first detector, that is tuned to the signal frequency of 2738 kilohertz.

606. Why should a superheterodyne receiver used for the reception of A1 signals be equipped with at least one stage of radio-frequency amplification ahead of the first detector?—The two major reasons are to prevent local-oscillator radiation (and possible interference with other stations) and to provide an improvement in sensitivity and signal-to-noise ratio (with the resultant ability to copy very weak cw signals).

607. If a superheterodyne receiver is receiving a signal on 1000 kHz, and the mixing oscillator is tuned to 1500 kHz, what is the intermediate frequency?—It is 1500 — 1000 = 500 kHz.

608. What is the chief advantage to be gained from utilizing a high intermediate frequency in a superheterodyne receiver?—The image-frequency rejection is improved because there is a greater separation between the desired signal frequency and the image frequency.

609. What is the purpose of a receiver oscillator that operates on a frequency near the intermediate frequency of the receiver.—This oscillator is usually referred to as the beat-frequency oscillator, or bfo. Its purpose is to render an incoming cw signal audible. When a cw signal is received, it consists of the interruption of the intermediate-frequency carrier in accordance with the marks (dots and dashes) of the Morse code. The beat-frequency oscillator is tuned very near to the intermediate frequency being demodulated by the second detector. In effect, the oscillator makes the incoming code message audible as a series of interrupted audio tones corresponding to the original carrier on-off sequence of the received A1 signal.

610. How is automatic volume control accomplished in a receiver?—Automatic volume control is accomplished by rectifying the incoming carrier and developing a dc component that corresponds to the strength of that carrier. This dc voltage is then used to bias several of the intermediate-frequency (i-f) amplifiers and the radio-frequency (rf) amplifier, if included, in such a manner that their bias increases as the level of the incoming carrier becomes stronger. The net effect is to control the overall gain of the receiver automatically so that it does not overload with the reception of a strong signal and at the same time displays maximum sensitivity to the reception of a weak signal. Refer to the next question.

611. Draw a circuit diagram of a superheterodyne receiver with automatic volume control, and explain the principle of operation.—The seven-stage receiver in Fig. 12-12 has a radio-frequency section, or tuner, composed of an rf amplifier, a mixer, and a local oscillator. This is followed by an i-f amplifier with bfo; a combination diode detector, avc tube, and first audio stage; and finally an audio power amplifier. The avc bias is applied to the control grids of the i-f amplifier and rf amplifier.

There are three resonant circuits associated with the tuner; these are located in the respective grid circuits of the rf amplifier, mixer, and local oscillator. These three resonant circuits are tuned simultaneously with a three-section variable capacitor. As these capacitor sections are tuned over their frequency range, the intermediate frequency at the output must be maintained at exactly 455 kHz. Preset adjustments are included to maintain this tracking. Notice that there is a small trimmer capacitor across each resonant circuit. These trimmers are adjusted separately for proper tracking at the high-frequency end of the band. Likewise, there is a core associated with each of the coils in the resonant circuits; these cores can be adjusted separately to ensure proper tracking at the low-frequency end of the band. Note that the grid circuit of the rf amplifier is returned to the avc line. Capacitor C2 and resistor R1 are avc line filters. The rf amplifier and mixer have screen-voltage

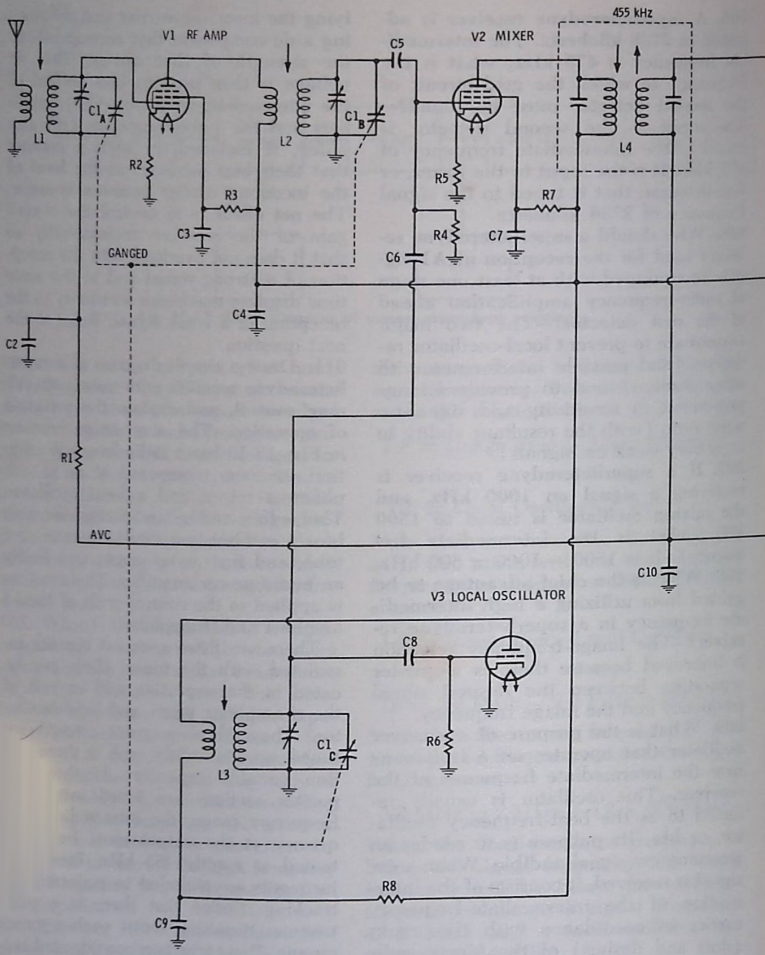
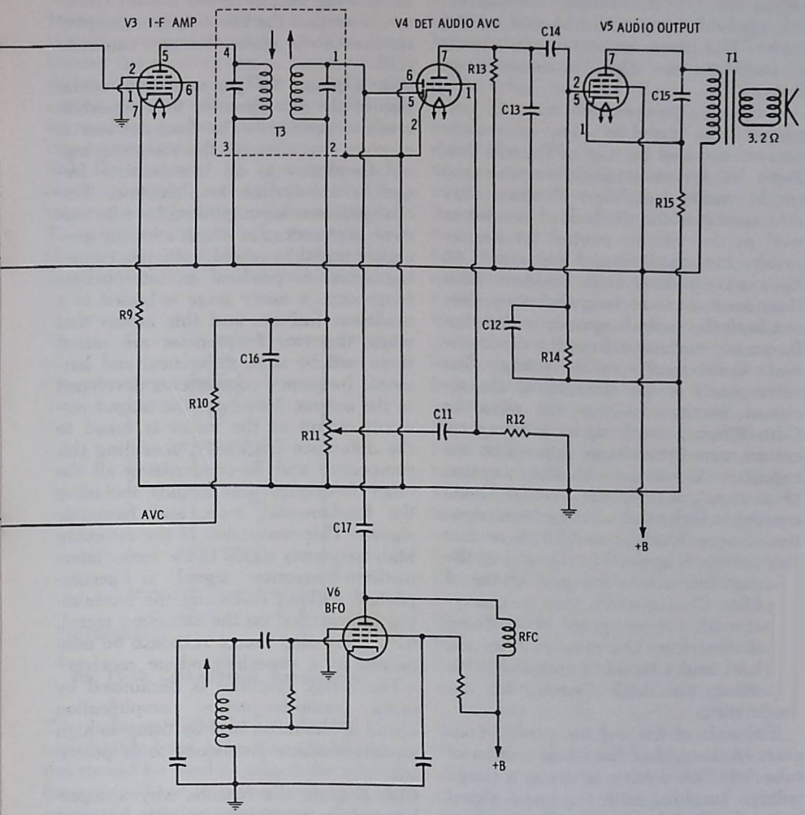


Fig. 12-12. Circuit of

dropping resistors along with screen filter capacitors. To ensure stability, a small amount of degenerative feedback is obtained with resistors R2 and R5, and also set the bias for the respective stages.

The local oscillator uses a tickler coil that supplies feedback from the plate circuit to the grid circuit in Armstrong fashion. The grid circuit is tuned by one of the tuning-gang sections so that it will track with the rf and mixer input circuits. However, the oscillator operates at a higher frequency than the signal frequency, the mixing then producing the desired 455-kHz intermediate frequency.



superheterodyne receiver.

Although the mixer and oscillator are separate stages, the pentode and triode sections are often contained in the same tube envelope. Local-oscillator injection into the mixer grid is made by way of a small capacitor (C6). For good performance, the oscillator injection voltage must be several times greater than the signal voltage. Too high an injection voltage is to be avoided because oscillations may reach the antenna system and be radiated. Oscillator radiation by the antenna can be a problem when the antenna is connected directly to the mixer. In this circuit, the rf stage provides appropriate isolation. Note that both the

signal and local-oscillator components are applied to the control grid of the mixer. The plate output resonant circuit is tuned to the 455-kHz intermediate frequency.

A single pentode i-f stage is employed. It is biased by a low-value cathode resistor and by way of the avc line. Tube V4 serves as diode detector and triode audio amplifier. Potentiometer R11 serves as the diode load resistor as well as the volume control for the receiver. Resistor R10 and capacitor C10 have a very long time constant. This time constant is so long that they filter out both the radio-frequency and audio-frequency variations from the diode circuit. Consequently, a dc voltage that corresponds to the strength of the received carrier develops on capacitor C10. When a weak signal is being received, very little charge appears on the capacitor. However, with the reception of a strong signal, the average diode current is high, and a rather high negative charge develops on C10. Note that this voltage is applied to the grid of the i-f amplifier and to the grid of the rf amplifier. Consequently, their gain is reduced with the reception of a strong signal; therefore, the receiver does not overload, and a signal of normal level is applied to the diode detector for demodulation.

The arm of the volume control connects to the grid of the triode section of tube V4. This section serves as a triode voltage amplifier with the audio signal being developed across its plate load resistor, R13. The final tube is an audio power amplifier which builds up the power level of the signal to a level that can drive a speaker. An output transformer matches the low impedance of the speaker to the higher output impedance of the power-amplifier tube. Capacitors C12 and C15 roll off the audio response above the voice-frequency range.

Tube V6 acts as the bfo. It is an electron-coupled oscillator with the cathode, grid, and screen acting as a triode Hartley oscillator. The oscillator is tunable around the intermediate frequency and beats with the cw signal in the i-f amplifier to produce an audible tone at the output of the second detector. Note that the bfo output is coupled to the diode plate through capacitor C17.

612. Explain the purpose and operation of the first detector in a superheterodyne receiver.—The first detector is a mixer that changes the incoming signal frequency to an intermediate frequency for further amplification. This changeover is accomplished by a heterodyne beat system in which a locally generated signal is mixed with the incoming signal to produce an intermediate frequency. A mixer stage is biased in a nonlinear fashion, and this means that when the two frequencies are mixed there will be sum, difference, and harmonic frequency components developed in the output. However, the output resonant circuit of the mixer is tuned to the difference frequency, accenting this component and de-emphasizing all the other frequency components including the fundamental, sum, and harmonic signals. This conversion of the incoming high-frequency signal to the lower intermediate-frequency signal is accomplished without distorting the modulating information on the incoming signal.

613. How may image response be minimized in a superheterodyne receiver?—The image response is minimized by using radio-frequency amplification ahead of the mixer and by using as high an intermediate frequency as is practical.

614. Explain the reasons why a superheterodyne receiver may not be used successfully for reception of frequencies very near the frequency of the i-f amplifier.—Such frequencies, particularly if the signals are strong will pass directly through the receiver input circuit and i-f amplifiers. It will not be possible to tune them out, and they will interfere with the reception of a desired signal on some other nearby frequency. Such a receiver, if it were a multistage affair, would also have a tendency toward instability and self-oscillation.

615. Why do some superheterodyne receivers employ a crystal-controlled oscillator for the first detector?—Such an oscillator has high stability, keeping the

receiver tuned precisely to some spot frequency. Some receivers employ a series of switched crystals, and in that manner the receiver can be tuned to several spot frequencies. This type of operation is popular when the only signals to be received are on a relatively few precise transmitting frequencies.

616. How should a superheterodyne communications receiver be adjusted for maximum response to weak cw signals? To strong cw signals?—In the reception of a weak signal, the radio-frequency gain control can be set to maximum.

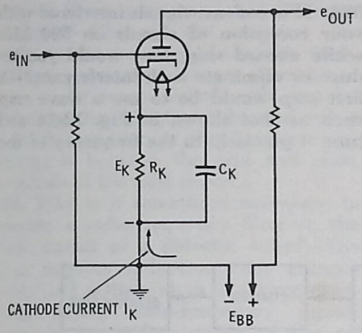


Fig. 12-13. Cathode-bias arrangement.

The audio gain should be adjusted to a comfortable level. Likewise, the bfo control should be used to adjust the tone of the received cw in accordance with the operator's copying preference. In some designs, additional improvement can be obtained by shutting off the avc. Also, if a means of adjusting the selectivity is included, it should be set for minimum interference and cleanest copying of the desired signal. In receiving a strong signal, the avc can be in operation. The radio-frequency gain control should be adjusted away from the maximum-amplification position. Turn back as far as possible without sacrificing loudness and clarity of the output signal. In the presence of interference, make the necessary selectivity adjustment. The audio gain and bfo are adjusted for preferred copying conditions and tone.

617. Draw a diagram showing a method of obtaining grid bias for an indirectly heated cathode type of vacuum tube by use of resistance in the cathode circuit of the tube.—See Fig. 12-13.

618. Why are the unused portions of inductances in receivers sometimes shorted?—Such shorting reduces losses and counteracts resonance effects that might make the receiver sensitive to images and other spurious frequency components.

619. What is a crystal filter as used in a superheterodyne receiver?—One or more piezoelectric crystals in conjunction with suitable inductor-capacitor combinations can be used to form a highly selective filter. These filters can be made with a very narrow bandwidth and with skirts that drop off very sharply. Their response characteristic is very stable and does not change with supply voltages, biasing, and other stage variables. Their purpose is to emphasize the desired signal and offer the highest rejection possible to signals on nearby and considerably removed frequencies that might interefere with the desired signal.

620. What is the purpose of a crystal filter in the i-f section of a superheterodyne communications receiver? Under what conditions is this filter used?—A crystal filter in the i-f system establishes the selectivity of the receiver. In effect, it controls the overall bandpass characteristic. It also makes the selectivity reasonably immune to circuit and other changes in the receiver. Refer to the previous questions.

Sometimes crystal filters are switchable. When the interference is severe and the frequencies around the desired signal are crowded, a filter can be switched into the circuit to establish a very narrow-band selectivity. The receiver must be tuned very precisely to place the desired signal on this sharp response curve. When a filter is used in this way, there will be a very sharp drop-off in the levels of signals on nearby frequencies, and this will improve the reception of the desired signal.

621. A radio receiver has a power transformer and rectifier designed to

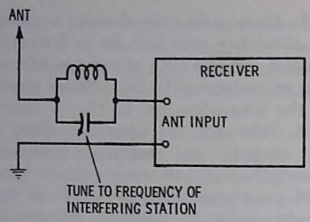


Fig. 12-14. Use of wave trap to reduce interference.

supply plate voltage to the vacuum tubes at 250 volts when operating from a 110-volt, 60-hertz supply. What will be the effect if the transformer primary is connected to a 110-volt dc source?—The power supply and receiver will be inoperative, and it is very likely that the primary of the transformer will be burned out or an associated fuse will be blown.

622. What is the purpose of a wave trap in a radio receiver?—Its purpose is to block the entrance into the receiver of high-powered interfering signals or signals from a nearby transmitter.

623. Draw a simple schematic diagram of a wave trap used in an antenna circuit to attenuate an interfering signal.—Refer to Fig. 12-14. A parallel resonant trap tuned to the frequency of the interfering signal can be placed in series with the antenna lead. A parallel resonant circuit has maximum impedance at resonance, and the interfering signal will be developed across the resonant circuit rather than appear at the receiver input.

624. If broadcast signals interfered with your reception of signals on 500 kHz while aboard ship, how would you reduce or eliminate such interference?—A first step would be to use a wave trap such as that shown in Fig. 12-14 and tune it precisely to the frequency of the

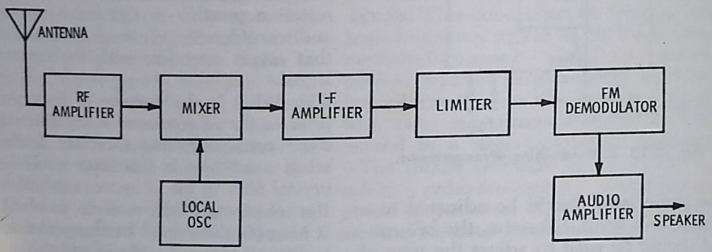


Fig. 12-15. Block diagram of fm receiver.

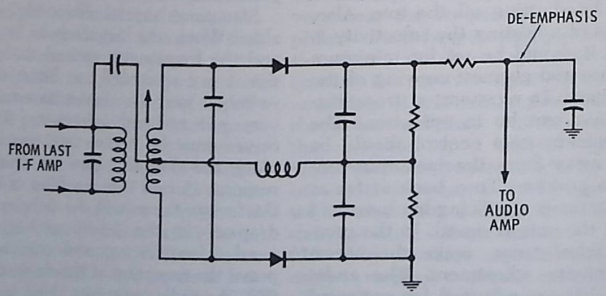


Fig. 12-16. Discriminator circuit.

interfering broadcast station. On occasion, the problem may be solved to a degree on a temporary basis by using another receiving antenna (such as switching from the regular antenna to the shorter reserve antenna) when you must operate in close proximity to a radio broadcast transmitter. This is sometimes a problem near a large city which may have a broadcast station operating at the low-frequency end of the broadcast band.

625. If the vacuum tube in the only radio-frequency stage of your receiver burned out, how could you make temporary repairs to permit operation of the receiver if no spare vacuum tube were available?—Connect the antenna directly to the input of the mixer stage with an appropriate jumper. Sometimes this can be accomplished with ease by removing the defective tube and using a small capacitor as the jumper, connecting it between the grid and plate terminals of the tube socket.

626. Why is it sometimes necessary to provide a radio-frequency filter in the plate circuit of a detector tube?—The filter removes radio-frequency components and is helpful in blocking especially strong radio-frequency signals from the succeeding stages of the receiver.

627. Compare the selectivity and sensitivity of the following receivers: (A) Tuned-radio-frequency receiver. (B) Superregenerative receiver. (C) Superheterodyne receiver.—The modern superheterodyne would be the most sensitive of the receivers, followed by the superregenerative and the frequency types. The sup receiver would also have t lectivity, followed in order radio frequency receiver a regenerative receiver.

FM RECEIVER

628. Draw a block diagra heterodyne receiver design ception of fm signals.—Se

629. What types of radio not respond to static interf quency-modulation (fm) less vulnerable to static Atmospherics and man-ma predominantly amplitude nature. Such amplitude be much more effectively the design of an fm recei receiver designed for the amplitude-modulated sig a-m receivers, properly de telegraph receivers with narrow bandwidth are lea to interference.

629. Draw a simple scher of an fm discriminator.— 12-16. The discriminator an fm receiver that is ab the incoming frequency audible amplitude chang process, the transmitted made to vary in accorda modulating information. occurs at an audio rate. T inator is able to convert variation that occurs at an an audio signal.

CHAPTER 13

Direction Finding and Alarm Systems, Element 6

DIRECTION FINDING

630. What is the directional reception pattern of a loop antenna?—It is a figure-eight pattern (Fig. 13-1).

631. What is the reception pattern of a vertical antenna?—It is an omnidirectional (nondirectional, or circular) pattern (Fig. 13-2).

632. What figure represents the reception pattern of a properly adjusted unilateral radio direction finder?—This is a cardioid pattern (Fig. 13-3).

633. How is the unilateral effect obtained in a direction finder?—It is the summation of the figure-eight loop pattern and the omnidirectional vertical-antenna pattern.

634. What is the principal function of a vertical antenna associated with a unilateral direction finder?—It permits a determination of the exact direction from which a received signal is arriving. A loop antenna has a bidirectional pattern and isolates the signal direction to two 180°-related bearings. The switching in of the vertical antenna makes it possible to obtain a unidirectional bearing.

635. What is indicated by the bearing obtained by the use of a unilateral radio direction finder?—Such a finder provides sense, indicating from which one of two bilateral directions the signal is arriving.

636. From how many simultaneous directions is a direction finder capable of receiving signals if adjusted to take unilateral bearings through 360°?—A cardioid pattern is such that there is one direction of minimum sensitivity and good sensitivity in all other directions. The point of maximum sensitivity is located 180° from the direction of minimum sensitivity.

637. What is the principal function of a vertical antenna associated with a bilateral radio direction finder?—A vertical antenna associated with a bilateral system permits the development of a figure-eight pattern with sharp nulls related by exactly 180°.

638. What is indicated by the bearing obtained by the use of a bilateral radio direction finder?—A bilateral bearing indicates a line of direction that includes the source of the received signal (sending station). The sending station is located toward either one of two directions that are 180° apart.

639. Why are loop antennas associated with radio direction finders metallically shielded?—The shielding helps to maintain the desired antenna pattern. It corrects for capacitive unbalances and other undesired antenna effects. The shielding is uniform and is broken by a small insulated section which acts as an entrance port for the received signal.

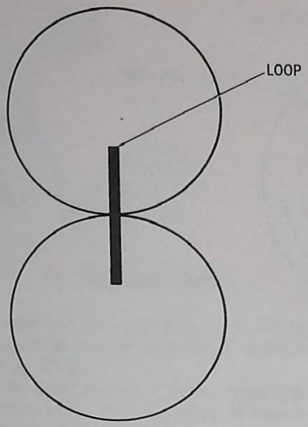


Fig. 13-1. Reception pattern of direction-finding loop.

640. What is the purpose of an auxiliary receiving antenna installed on a vessel which is also fitted with a direction finder?—A small auxiliary antenna can be used to maintain watch when the direction finder is in use or when it is anticipated that the direction finder will be used. When the direction finder is being used, no transmitter aboard ship may be put on the air, and in most installations the regular antenna system must be deactivated.

641. What is the function of the balancing capacitor in a direction finder?—Its purpose is to provide capacitive balance, minimizing the antenna effects that prevent the attainment of a sharp directional null.

642. What is a compensator as used with radio direction finders, and what is its purpose?—The compensator provides error correction so that the pointer of the direction finder indicates true bearing on the associated bearing card. Usually, it is a corrective mechanical device that is adjusted when the direction finder is calibrated after the installation aboard ship has been made.

643. Describe the construction and operation of a shielded loop antenna as used with a marine direction finder.—

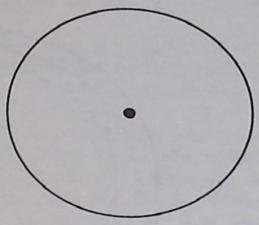


Fig. 13-2. Reception pattern of vertical antenna.

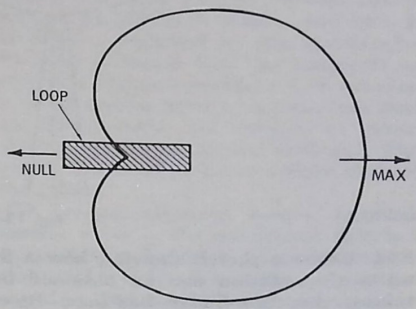


Fig. 13-3. Cardioid pattern resulting from combination of loop antenna and vertical "sense" antenna.

Refer to Fig. 13-4. A direction-finding loop is usually a shielded coil consisting of about 12 turns and measuring 3 feet in diameter. This is surrounded completely by a metallic shield except for a narrow insulated section at the top, where the received signal enters. On the opposite side, the output leads, surrounded by a continuation of the metallic shield, carry the received signal to the direction-finder receiver. This shielding is in the form of a shaft that continues to the location of the receiver, usually on the bridge of the vessel. It can be rotated by hand through its mechanical coupling to a wheel and associated bearing card. When the direction finder has been installed and calibrated, the pointer indicates the true bearing direction when the direction finder is rotated to the null position.

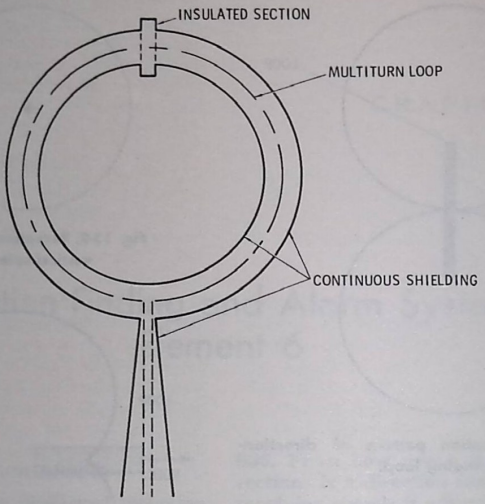


Fig. 13-4. A df loop.

644. Draw a sketch showing how a fix on a ship station can be obtained by taking direction-finder bearings.—Refer to Fig. 13-5. Several bearings are taken from different locations, and the position of the ship is at some point along each of the bearing lines. When these lines are drawn on a chart, their point of intersection indicates the precise position of the ship.

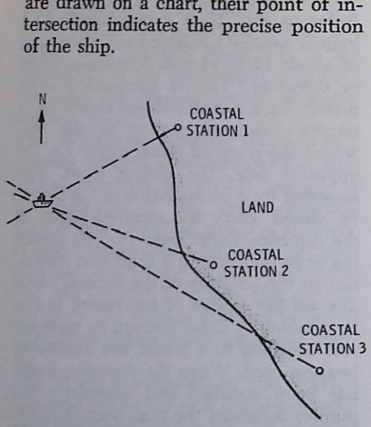


Fig. 13-5. Method of obtaining fix on position of ship.

645. Within what frequency-band limits do all United States marine beacon stations operate?—Assigned frequencies fall between 285 and 315 kHz.

646. On shipboard, what factors may affect the accuracy of a direction finder after it has been properly installed, calibrated, and compensated?—Accuracy can be harmed by a movement of some metallic surface near the direction finder after calibration or the addition of new metallic surfaces in the vicinity of the antenna. It is almost necessary that all the ship's antennas be installed before calibration of the radio direction finder. Any changes in these antennas may have an adverse effect on the direction-finder accuracy.

Abnormal sky-wave propagation, usually occurring at night, can also affect accuracy. The radio direction finder is designed to operate on ground-wave propagation.

LORAN

647. Draw a simple sketch showing the relative positions of pairs of master and slave stations of a loran navigation sys-

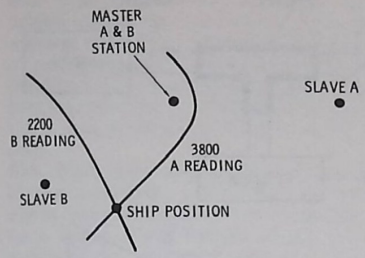


Fig. 13-6. Loran "fixing."

tem, and indicate the line of position of each pair of master and slave stations.—See Fig. 13-6.

648. In determining a fix or position by a marine loran system, what is the minimum number of land transmitters involved?—Two pairs of master-slave stations are involved, for a total of four transmitters. However, if a master station is double-pulsed to operate two stations, only three actual stations are required.

649. What is the relationship between a master and a slave station in reference to loran navigation systems?—The master station transmits the master pulse. This master pulse is also intercepted by the one or two slave stations for a time reference. After a prescribed delay time, the slave station transmits its own pulse. It is this precise delay interval, as well as the exact separation between master and slave, that permits the loran system to obtain an exact fix.

650. Explain why pulse emission, rather than continuous-wave emission, is used in loran transmitters. Approximately what pulse repetition frequency, pulse duration, and operating frequency are used in loran systems.—Continuous-wave emission is not feasible in the loran system because master and slave pulses are transmitted on the same frequency, and it is the individual pulses and their duration and timing that permit the accurate fixes that can be obtained by the loran system. Approximate pulse repetition frequencies are 20, 25, and 33 pps; the pulse duration is approximately 40 microseconds; and the frequency is in the range 1.75 to 1.95 MHz.

651. How can the operator of a loran receiver on shipboard identify the transmitting stations that are being received?—When the receiver is tuned properly, its associated indicator provides a read-out of the loran pair code, which can be used to identify the particular loran station. For example, if the loran station selector is set to 2H4, this means that the channel 2 station (1.85 MHz) is being received and that it operates at a precise pulse rate of 33⅓ pps.

652. What is the purpose of blinking in a loran navigational system, and how is blinking recognized at the receiver?—Blinking indicates that the transmitting station is having a problem with synchonization and/or timing and readings that are being taken are subject to error. Blinking is shown on the indicator display as an on-off pulse or a right shift of the pulse.

653. During daytime hours, approximately what is the maximum distance in nautical miles from a loran transmitting station that a loran line of position can be determined?—The distance is approximately 700 miles.

654. When several pairs of loran transmitting stations are operating on the same frequency, how does the operator at a loran receiver select the desired pair of transmitting stations?—He selects the proper station by choosing the correct pulse repetition rate, or pulse recurrence rate.

RADAR

655. In what part of the radio-frequency spectrum do marine radar systems operate?—They operate in the 3-cm (10,000 MHz) and 10-cm (3000 MHz) regions.

656. Draw a simple block diagram showing the essential components of a radar system. Label the components such as receiver, indicator, etc.—See Fig. 13-7.

657. If the velocity of a radio wave is 186,000 statute miles per second, how many nautical miles does a radar pulse travel in 1 microsecond?—Since 186,000

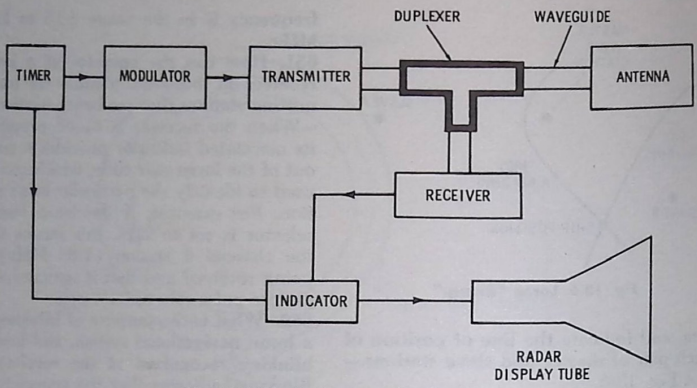


Fig. 13-7. Block diagram of radar set.

statute miles and 162,000 nautical miles are the same distance, the nautical miles traveled by a radar pulse in 1 microsecond would be $162{,}000/10^6 = 0.162$.

658. What is the average plate power input to a radar transmitter if the peak power is 15 kilowatts, the pulse length is 2 microseconds, and the pulse repetition frequency is 900 hertz?—It is first necessary to determine the total transmitting time per second and then the duty cycle. Since the pulse length is 2 microseconds and the repetition frequency is 900 pulses/second, the transmitting time is 1800 microseconds (2×900). The duty cycle is found by dividing this quantity by the number of microseconds in a second or:

$$\text{Duty Cycle} = \frac{\text{Transmitting Time}}{10^6}$$

$$= 0.0018$$

Inasmuch as the peak power is known, the average power can be determined by multiplying the peak power times the duty cycle, or:

$$\text{Average Power} = 0.0018 \times 15{,}000$$

$$= 27 \text{ watts}$$

659. Approximately at what speed does the antenna of a navigational radar rotate?—Typical rotation speeds are between 6 and 30 revolutions per minute.

660. How should a radar set be adjusted by the operator to reduce sea return?—This adjustment is handled with the sensitivity time control (STC). Reduce the sensitivity with this suppression control until the pattern of the sea return begins to fade out, making the target signals more discernible.

661. What precautions should an operator or serviceman observe when working with cathode-ray tubes and the associated circuits of radar and loran receivers?—Cathode-ray tubes, because they are large and evacuated, can implode, hurling dangerous glass particles at high velocity. Gloves and safety goggles are in order. Such tubes should not be struck sharply or hit against hard surfaces. Cathode-ray circuits also operate at very high voltages, and technicians must be especially careful when working on internal circuits. High-voltage capacitors are capable of holding a charge for a lengthy period of time, and they should be discharged by grounding before the technician works on associated circuits.

ALARM SYSTEMS

662. To what frequency, or band of frequencies, is an approved autoalarm receiver tuned?—An autoalarm receiver tunes 500 kHz $\pm$12.5 kilohertz.

663. What signal will cause an approved autoalarm receiver to ring the warning bell?—Four consecutive dashes of proper duration and spacing set off the alarm. The dash duration may range between 3.5 and 4.5 seconds; the separation may be between 0.1 and 1.5 seconds.

664. What factors determine the setting of the sensitivity control of an autoalarm receiver approved for installation on a vessel of the United States?—The setting of the sensitivity control depends on interference and static present. The receiver sensitivity must be set to a point that will permit actuation by a weak received signal, but at the same time, the alarm should not be set off by noise or interference. One backs off the sensitivity control until the relay chatters under the presence of noise and interference but does not set off the receiver alarm.

665. On a vessel of the United States equipped with an approved type of autoalarm which employs a linear detector and an electronic selector, what factors cause the bell to sound? The warning light to operate?—The electrical factors that cause the bell to sound are a true autoalarm signal or a false signal caused by interference (the latter will not be of a repeating nature). Circuit defects, such as improper line or battery voltage or an open vacuum-tube filament circuit, sound the bell.

The warning light operates with the reception of a true autoalarm signal, interference that lasts in excess of several seconds, low or absent battery voltage, or too high a setting of the sensitivity control.

666. With an autoalarm of the type which employs a square-law detector and a mechanical selector, what factors cause the bell to sound? The warning light to operate?—The bell will operate under the same conditions stated for the previous question, or for any of the following reasons: an open 24-volt circuit to the receiver or autoalarm equipment, a blown fuse in the battery charger, or a stopped or slowly running motor.

The warning light also operates for the reasons given in the answer to the previous question.

667. With an autoalarm of the type which employs a linear detector and an electronic selector, what is the most probable cause of the intermittent ringing of the bell?—Usually it is an indication of supply voltage variation beyond a specified limit.

668. On a vessel of the United States with an approved type of autoalarm which employs a linear detector and an electronic selector, what would happen upon failure of a vacuum-tube filament?—The alarm bell would be set off.

669. If an autoalarm bell rings and upon pressing of the release button it stops, what could be the cause(s)?—This indicates that a true alarm signal or a false interference signal has set off the alarm.

670. If an autoalarm bell rings and upon pressing of the release button it does not stop, what could be the cause(s)?—This would usually be caused by low or absent voltages, an open filament, or other circuit defects.

671. With an autoalarm of the type which employs a square-law detector and a mechanical selector, why does this alarm receiver not respond to A1 emission?—This type of receiver responds to the modulation on a received signal; none is present with A1 emission.

672. If a vacuum-tube heater burns out in an approved autoalarm, what causes the warning bell to ring?—There is a heater relay which becomes de-energized. When this happens, a pair of contacts closes and energizes the bell relay.

673. What means usually is provided to prevent the operation of the ship transmitter when the autoalarm receiver is in use?—In the operate position of the autoalarm antenna switch, there is a simultaneous disconnection of the transmitter keying system.

CHAPTER 14

Rules and Regulations, Element 6

674. What is the primary standard of frequency for radio-frequency measurements for all licensed radio stations?—The primary standard of radio-frequency measurement is maintained by the National Bureau of Standards, Dept. of Commerce, Boulder, Colo. The operating frequency of radio stations is determined by comparison with this standard or the standard signals transmitted by WWV. (RR 2.1)

675. What is the meaning of frequency tolerance?—Frequency tolerance refers to the extent to which an actual or suppressed carrier frequency is permitted to depart from the authorized carrier frequency. Frequency tolerance is expressed in parts per million or in hertz (RR 83.7).

676. For what period of time must a station log which contains entries incident to a disaster be retained?—It must be retained for a period of three years from date of entry. (RR 83.115)

677. Under what circumstances may a station be operated by an unlicensed person?—No station may be so operated. However, this restriction may be waived by the Federal Communications Commission if it finds that the public intertest, convenience, or necessity will be served. This does not apply to broadcast stations and stations operated by common carriers on frequencies below 30 MHz. Other exceptions are stations licensed for safety purposes and stations requiring licensed operators by international agreement. The Commission can exempt certain automatic radio devices.

678. In all cases other than those in which the transmitter output must be maintained at a fixed value, what amount of power should be employed for routine communications?—Power should be limited to that amount necessary for reliable communications.

679. What is the definition of a station open to public service?—This refers to a station open for public correspondence. Public correspondence is any telecommunication which the offices and stations must, by reason of their being at the disposal of the public, accept for transmission.

680. If an operator performs service or maintenance duties at more than one station, how may he comply with the rule requiring the posting of operator licenses?—In lieu of posting, he may have on his person either his license or a verification card. (RR 13.74)

681. In the transmission of International Morse Code, what are the relative time lengths of dashes, dots, and spaces?—A dash is equal to three dots. The space between signals forming the same letter is equal to one dot. The space between two letters is equal to three dots. The space between two words is equal to seven dots.

682. Why is the clock in a compulsorily equipped ship radiotelegraph station

required to have a sweep second hand?—Such a clock is required to be visible from the operating position which would ordinarily be used to transmit the international radiotelegraph alarm signal by hand and from the position used for testing a radiotelegraph autoalarm. Such a clock is also necessary to time the quiet period precisely. (RR 83.114)

683. Between what points on a ship compulsorily equipped with a radiotelegraph installation is a reliable intercommunication system required?—An intercommunication system must be provided between the bridge of the ship and the radiotelegraph operating room except when the two locations adjoin. A similar communication facility must exist between the bridge and the location of the radio direction-finding apparatus. (RR 83.466)

684. What experience is the holder of a first- or second-class radiotelegraph operator license required to have before he is permitted to act as chief or sole operator on a compulsorily radio-equipped cargo ship?—He must have at least six months of aggregate satisfactory service in a station on board a ship or ships of the United States as a qualified radiotelegraph operator. (RR 13.61)

685. Are there any age requirements that a person must meet before he can be issued a radiotelegraph operator license?—A radiotelegraph first-class operator must be at least 21 years of age. (RR 13.12)

686. What action, if any, may a radio operator take when he observes a ship's station flagrantly violating the international radio regulations and causing harmful interference to other stations?—A report should be submitted to the Federal Communications Commission. The form of such a complaint is set forth in Appendix 7 to the International Radio Regulations. (RR 83.602)

687. On compulsorily equipped vessels which are required to have an accurate clock in the radio room, how frequently must this clock be adjusted and compared with standard time?—A daily log entry shall be made regarding comparison of the radio-station clock with standard time. (RR 83.330)

688. Under what conditions may a ship station close if its service is not required to be continuous?—Closedown is not permitted until all operations resulting from a distress call or urgency or safety signal are finished. Closedown is not permitted until, so far as practicable, the station has exchanged all traffic originating in or destined for coast stations situated within its range and mobile stations which, being within its range, have indicated their presence before the actual cessation of work. (ART 35-11)

689. What exceptions are permitted to the regulation which states that a ship station which has no fixed working hours must advise the coast station with which it is in communication of the closing and reopening time of its service?—A mobile station arriving in port whose service is about to close must so notify the nearest coast station and, if necessary, the other coast stations with which it generally communicates. There is no indication that its time of reopening must be conveyed. (ART 35-11 & 12)

690. How frequently should entries be made in a ship's radiotelegraph log while a radio watch is being maintained?—The entry on watch shall be made by the operator beginning a watch, followed by his signature. The entry off watch shall be made by the operator being relieved or terminating a watch, followed by his signature. All log entries shall be currently completed at the end of each watch by the operator responsible for the entries. The use of initials or signs is not authorized in lieu of the operator's signature. (RR 83.330)

691. At what time(s) must the international silent period be observed?—The silent period must be observed for three minutes twice an hour beginning at 15 minutes after the hour and 45 minutes after the hour, Greenwich Mean Time. (ART 33-9)

692. At what time(s) are routine transmissions forbidden in the 485- to 515-kHz bands?—Transmissions are not permitted on this band of frequencies during the silent period given in the answer to the previous question. This ensures a clear channel for maintaining watch on

the international distress frequency of 500 kHz. (ART 33-9)

693. Under what circumstances must log entries be made regarding observance of the international silent period?—Sign-on watch and sign-off watch entries must be made (refer to question 690). When an operator is on watch, an entry shall be made twice per hour stating whether or not the international silent period was observed. In addition, entries shall be made indicating signals or communications heard on 500 kHz during this period. If no signals are heard on 500 kHz, an entry to that effect shall be made. (RR 83.330)

694. What time system shall be used in making log entries with respect to the observance of the international silent period?—Time shall be expressed in Greenwich Mean Time (GMT). An exception applies to vessels navigating on the Great Lakes or the inland waters of the United States. Entries on the Great Lakes can be made in Eastern Standard Time (EST), counted from 0000 to 2400 o'clock beginning at midnight. For other inland waters, local standard time may be used, counted from 0000 to 2400 o'clock. (RR 83.330)

695. What is the international radiotelegraph distress frequency for stations in the mobile service?—The international radiotelegraph distress frequency is 500 kHz (ART 37-4)

696. Describe how a distress call should be made.—The distress call sent by radiotelegraphy comprises the distress signal transmitted three times, the word DE, and the call sign of the mobile station in distress sent three times. (ART 37-8)

697. What transmission should precede the transmission of the distress call?—The distress call when sent by radiotelegraphy on 500 kHz is, as a general rule, preceded by the alarm signal. (ART 37-9)

The alarm signal consists of a series of twelve dashes sent in one minute, the duration of each dash being four seconds and the duration of the interval between two consecutive dashes being one second. It may be transmitted by hand, but its transmission by means of an automatic instrument is recommended. The actual distress call in radiotelegraphy consists of the group · · · — — — · · · (dot, dot, dot; dash, dash, dash; dot, dot, dot), in which the dashes must be emphasized so as to be distinguished clearly from the dots.

698. What station shall be in control of distress traffic?—The control of distress traffic is the responsibility of the mobile station in distress, or of the mobile station which, by the application of appropriate provisions, has sent the distress call. These stations, may however, delegate the control of the distress traffic to another station. (ART 37-22)

699. During what period must a distress message be repeated following the initial transmission?—The distress message must be repeated at intervals, especially during the period of silence, until an answer is received. (ART 37-16)

700. During what periods must the safety signals be transmitted?—The safety signal should be transmitted toward the end of the first available period of silence; the actual message is transmitted immediately after the period of silence. (ART 37-42)

701. How long must mobile stations listen after hearing an urgency signal?—Mobile stations must continue to listen for at least three minutes. (ART 37-38)

702. Describe the number of dashes, dots, and spaces which compose the international autoalarm signal, and indicate the time intervals involved.—The alarm signal consists of a series of twelve dashes (no dots) sent in one minute. The duration of each dash is four seconds, and the duration of the interval between two consecutive dashes is one second. The signal may be transmitted by hand, but its transmission by means of an automatic instrument is recommended. (ART 37-30)

703. When the autoalarm bell rings, what should the operator do?—The operator should depress the reset button of the autoalarm in the radio room. If the bell stops, the operator should listen for further signals to determine if there has been a true or false alarm signal. If there has been a true signal, he must begin a watch on the distress frequency immedi-

ately. When the bell does not stop ringing after the reset button has been depressed, an equipment defect is indicated.

704. Under what circumstances and by whom may the international autoalarm signal be transmitted to announce an urgent cyclone warning?—An autoalarm signal coming ahead of an urgent cyclone warning may be transmitted only by duly authorized coast stations. (ART 37-30)

705. What space of time should elapse between the transmission of the international autoalarm signal and the distress call?—When circumstances permit, the transmission of the call is separated from the end of the alarm signal by an interval of two minutes. (ART 37-9)

706. While a vessel is at sea, how frequently must the autoalarm be tested?—Every 24 hours. (RR 83.457)

707. What interval of time must elapse between the end of the autoalarm signal and an urgent cyclone warning?—The warning must not begin until two minutes after the end of the alarm signal. (ART 37-30)

708. Under what circumstances is a station in the mobile service not required to listen to distress traffic?—A station may operate when the distress traffic is well established and on condition that it observes appropriate provisions and does not interfere with the distress traffic. (ART 37-24)

709. Upon hearing an SOS, what should an operator do?—The distress call has absolute priority over other transmissions. All stations which hear it must immediately cease any transmissions capable of interfering with the distress traffic and must listen on the frequency used for the emission of the distress call. This call must not be addressed to a particular station, and acknowledgement of receipt is not to be given before the distress message is sent. (ART 37-13)

710. What is the purpose of an autoalarm-signal keying device on a compulsorily equipped ship?—Such a device produces an alarm signal automatically. It must not be keyed by the operator. It alerts other stations so that they can prepare for receiving a distress call.

711. On a vessel of the United States equipped with an approved autoalarm, where is the control button which silences the warning bell located?—It is a manual switch located in the main radiotelegraph operating room.

712. With what type(s) of emission and on what frequency should a radiotelegraph transmitter be adjusted to transmit a distress call?—The call should be transmitted on the international distress frequency of 500 kHz (600 meters), preferably using type A2 or B emission.

713. If you receive a distress call signed by a call signal composed of five letters, could you determine the type of craft which transmitted the signal?—Yes. Aircraft are assigned five-letter calls. (ART 19-5)

714. While the vessel is on the open sea, how frequently must the specific gravity of the emergency battery be taken?—This must be done each day. (RR 83.449)

715. How frequently must the quantity of fuel in the supply tank for use with an oil- or gas-driven emergency generator be checked while the vessel is on the open sea?—Each day. (RR 83.449)

716. While a vessel is in port, how frequently should the emergency equipment be tested?—Test must be made just prior to departure. (RR 83.449)

717. You intercept "CQ, CQ, WSV, TFC, QSY, 735 AS." What does this mean?—Refer to Appendices III and IV. Coastal station WSV is sending out a general call indicating that a traffic (TFC) list will be transmitted. A frequency change (QSY) will be made to 735 meters. A waiting period (AS) permits time to QSY to 735 meters.

718. Upon hearing a safety signal, what should the operator at the receiving station do?—All stations hearing the safety signal must continue to listen on the frequency on which the safety signal has been transmitted until they are satisfied that the message is of no interest to them. They must, moreover, not make any transmissions likely to interfere with the message (ART 37-43)

719. Explain the use and meaning of the following indicators or prefixes on

radiotelegrams, and describe the difference in handling of the various types of radiotelegrams: RP, TC, TR, FS, PR, PC, MSG, CDE, OBS, PDH, CODH.—

RP: Reply-prepaid message. This means the sender has prepaid the reply message to a specified limit.

TC: Collated message. In this type of message, the copy is sent back to the sender by the receiving station for verification. An extra charge is made.

TR: Deliver to place. Will be picked up by addressee.

FS: Forward telegram to addressee. Sender quarantees to pay additional charges.

PR: Deliver by registered mail.

PC: Acknowledge delivery of message. Coast station informs the sender as to the time and date the message was delivered to the ship.

MSG: Master's messages. They represent free exchanges of traffic between masters of vessels regarding ship's business.

CDE: Coded message consisting of five-letter coded word in the text.

OBS: Meteorological reports, sent to the U.S. Weather Service.

PDH: Franked or free message.

CODH: A company business franked message. Usually message requests repair, relief, or other business information.

720. Explain cable count and the use of standard service abbreviations, and show the difference between cable count and domestic word count.—Counting has to do with the message information that is sent and the manner in which a charge is made. In the domestic service, the sender is charged only for the text. In a cable count, a charge is made for everything that is sent (address, text, and signature).

There are various types of standard service abbreviations. These are usually acceptable abbreviations that can be sent to avoid a higher word count. For example, ETA refers to estimated time of arrival, GMT refers to Greenwich Mean Time, etc.

Message words are counted in the following manner: Any name or word in the text up to 15 letters counts as one word. In establishing the charge, a word or name with a letter count between 16 and 30 has a two-word charge. In the address, groupings of more than 15 letters will be charged on a one-word basis. For example, Philadelphiapennsylvania strung together would be one word.

721. Construct a plain-language radiotelegram and indicate the portions that make up (A) the preamble, (B) the address, (C) the text, and (D) the signature.

(A) Preamble:

P 21
(paid) (msg number)
8 SS LANCE
(words) (from)
10 1310
(date) (time)

(B) Address:

John Jones, Golden Lines, New York

(C) Text:

ETA 11 1000Z Wait
(Estimated arrival time 11th at 1000 GMT)

(D) Signature:

Ed Jones

722. On what band, in addition to the 350-515 kHz band, must a main receiver on a United States ship be capable of operation? What is the purpose of this additional band?—The main receiver must be capable of receiving A1 and A2 emissions on frequencies between 100 and 200 kHz. This band is used for transmitting long-wave, long-distance radiotelegraph communications. (RR 83.444)

723. If, upon being called by another station, a mobile station is unable to proceed with the acceptance of traffic, what should the operator of the called station do?—The call is acknowledged by the receiving station, but the last letter K is replaced by the wait signal (AS), followed by a number indicating, in minutes, the probable duration of the waiting time. If the probable delay ex-

ceeds ten minutes, the reason for the delay must be given. (ART 29-15)

724. After a distress call has been transmitted, every distress traffic radiotelegram shall contain what symbol in the preamble?—In distress traffic, the distress signal must be sent before the call and at the beginning of the preamble of any radiotelegram. (ART 37-21)

725. For how long a period of continuous operation should the emergency power supply of a compulsorily equipped ship station be capable of energizing the emergency radiotelegraph installation?—For a period of 6 hours. (RR 83.446)

726. While the vessel is on the open sea, how frequently must the emergency equipment be tested?—It should be tested each day. (RR 83.449)

727. Indicate the order of priority of the various types of radiocommunications.—Distress calls, communications preceded by the radiotelegraph urgency signal, communications preceded by the international radiotelegraph safety signal, communications relative to radio direction-finding bearings, communications relative to navigation and safe movement of aircraft, communications relative to the navigation and movement of ships, government communications for which priority has been claimed, service communications, and all other communications. (RR 83.177)

728. What is the principal port of the United States on the Pacific coast, at which navigation lines terminate?—San Francisco.

729. In what city is the major telecommunication center of the United States located?—New York City.

730. What is the approximate latitude of Colon, Republic of Panama?—This city is north of the equator at an angle of approximately 9.4° N.

731. In what ocean is the island of Guam located?—Pacific Ocean.

732. To what continent do the greatest number of telecommunication channels from the United States extend?—The continent of Europe.

733. What is the principal Atlantic coast port of the United States at which navigation lines terminate?—New York City.

734. What are the time (GMT) and the day of the week in Shanghai when it is Wednesday noon in New York City?—The GMT would be the same in New York City and Shanghai. Since there is a five-hour differential between GMT and New York City time, noon in New York City corresponds to 1700 GMT (12 + 5) Wednesday. However, Shanghai is on the other side of the international date line. Therefore, the time and day in Shanghai would be 1700 GMT Thursday (1 a.m. Shanghai local time).

735. In a ship radiotelegraph station, where may information be found concerning the forwarding charges for radiotelegrams?—The station licensee usually has a tariff book available. General information is also available from the International Telecommunications Union.

CHAPTER 15

Radar, Element 8

Element 8 need not be passed to obtain a second-class radiotelegraph license. However, it is important that you obtain the ship radar endorsement because most modern vessels do have a radar installation.

This special endorsement element consists of fifty questions covering specialized theory and practice applicable to proper installation, servicing, and maintenance of ship radar equipment.

This chapter covers the Element 8 Ship Radar Technique questions as given in the FCC *Study Guide and Reference Material for Commercial Radio Operator Examination.* To obtain the radar license endorsement, you must pass an examination based on these questions.

Questions and answers have been rearranged for good study continuity. A short, direct answer is given for each question. You are also directed to detailed discussions in Chapter 2. This follow-up study will permit you to acquire a greater depth of understanding, and you will be better prepared for the different ways a question of this type might be presented in a multiple-choice examination. This study process is not only an aid to memory, it also gives you the knowledge you will need when you begin to work on actual radar sets. In particular, spend some extra effort on Chapter 2 because it treats in detail the topics of a high percentage of the questions that are given in the examination. Additional references are made to the specific radar rules and regulations given in Appendix II.

RADAR PRINCIPLES AND LAWS

1. Draw a block diagram of a radar system, labeling the antenna, duplexer, transmitter, receiver, modulator, timer, and indicator.—See Fig. 15-1.

2. Briefly explain the principle of operation of a radar system.—The transmitter sends out a pulse of radio-frequency energy to a reflecting target. Some of the reflected energy returns to the radar set and is picked up on the receiver. Since radio waves travel at a constant speed, the radar set, by evaluating the time needed for the radio energy to make a round-trip excursion, determines the distance, or *range,* to the target. The angle at which the antenna is directed when radar pulses make such a round trip to a target indicates the *bearing* of the target.

The timer (Fig. 15-1) establishes the number of pulses that are sent out each second. In so doing, it also establishes the transmitting and receiving times of the radar set. Under control of the timing pulse, a power pulse is formed in the modulator. This power-modulator pulse turns the magnetron oscillator on and off at the described pulse rate. It is the magnetron that forms the burst of mi-

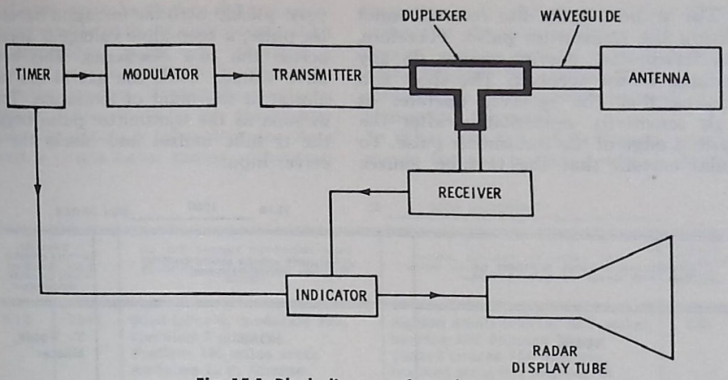


Fig. 15-1. Block diagram of a radar set.

crowave rf energy which is fed to the antenna through a duplexer and waveguide. The duplexer provides the necessary isolation to permit one antenna to be used for both transmitting and receiving. The return signal is fed to the receiver, where it is amplified and detected. It is then passed to the indicator. The indicator, under control of the timing pulses, generates the sweep and calibration waveforms needed by the radar display tube. The return signals are also applied to the radar display tube. The radar tube is a cathode-ray type, and the target information is painted on its fluorescent screen. Range, bearing, and other target attributes can be measured and observed on the display pattern.

3. Draw a simple block diagram of a radar duplexer system, labeling the waveguide, tr box, anti-tr box, receiver, and transmitter.—See Fig. 15-2.

4. Briefly describe the construction and operation of radar tr and anti-tr boxes. What is the purpose of a keep-alive voltage?—The tr and anti-tr boxes are inserted in the duplexer to provide optimum isolation between transmitter output and receiver input, making it possible to use a single antenna for transmitting and receiving. The boxes are usually a part of a waveguide assembly so that they do not introduce any discontinuity in the signal paths. The tr and atr tubes themselves are gas diodes which ionize and arc under excitation of the high voltage of the transmitter pulse. Thus, both tubes are ionized and act as short circuits during the transmitter pulse.

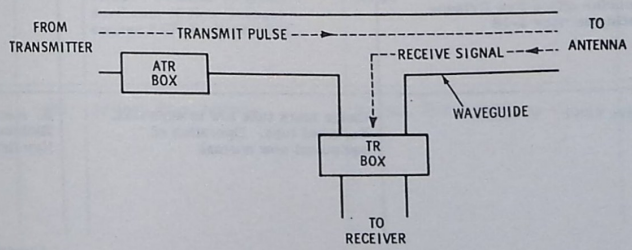


Fig. 15-2. Radar duplexer system.

The tr box shorts the receiver input during the transmitter pulse. Therefore, the transmitter energy cannot do any damage to the receiver. The short also ensures that the receiver operates at high sensitivity immediately after the trailing edge of the transmitter pulse. To make certain that the tr tube ionizes very quickly with the initiation transmitter pulse, a keep-alive voltage is applied across the two electrodes. This keep-alive voltage holds the gas in the tube almost at the point of ionization. Thus, as soon as the transmitter pulse begins, the tr tube ionizes and blocks the receiver input.

YEAR 1960

OPERATIONAL FAILURES: DURATION, NATURE AND CAUSE OF EACH FAILURE.	ADJUSTMENTS AND/OR REPAIRS EFFECTED BY SERVICE PERSONNEL.	SIGNATURE, TITLE & PORT, FCC LICENSE NO. DATE OF RADAR ENDORSEMENT.
NONE	NONE	T. Woods, Master
NONE	NONE	J. Walker, 2d Mate
Noted occasional disappearance of fixed range rings. Wired radiomarine office New Orleans requesting service 2-18	NONE	T. Woods, Master
Defective 6SN7 V-1010	Range mark tube low in emission. Replaced tube. Operation of equipment now normal	R. Johnson Radiomarine New Orleans

Courtesy RCA

Fig. 15-3. Sample

The atr box is located in the transmitter waveguide path. It also ionizes with the transmitter pulse and provides a path of transmission from the transmitter to the antenna. During the receiving interval, when there is no transmitter pulse, the atr and tr tubes deionize. As a result, a return signal passes without attenuation into the receiver input. Because the atr tube is deionized, an incoming signal sees a high-impedance path toward the transmitter, and is routed into the receiver instead of the transmitter channel.

5. What are the FCC license requirements for the operator who is respon-

RADAR LOG SS ESSO PATTERSON

MONTH AND DAY	TIME AM PM	SEA AND WEATHER CONDITIONS. WIND FORCE, VISIBILITY, RAIN, FOG, SNOW CONDITIONS, APPROXIMATE POSITION, COURSE.	UNUSUAL INCIDENTS OF RADAR OPERATION WHERE SAFETY OF VESSEL WAS AIDED OR HINDERED.	ELAPSED TIME HOUR METER READING.
2-10	1244	Wind force 4, moderate sea, visibility 1 mile. Position 120 miles south Ambrose L. V. Course 3 degrees True	Sighted small trawler at 5 miles, bearing 358 degrees True-plotted course 154 degrees, tracked down till bearing 45 degrees True, range 800 yards	325
2-15	0430	Wind force 5, moderate sea, morning haze, visibility ½ mile. Proceeding on course 160° T. Speed 12 approximately 20 miles south Mantanilla Buoy	Contacted target at 7.5 miles two points off port bow at 0525. Visibility now 3 miles. Sighted buoy 2 points forward of port beam at 3 miles (by radar range) 0540. Buoy abeam at 0554, changed course 193° T. Speed 12	417
2-17	1045	Wind force 10, moderate sea, partly cloudy, visibility 7 miles. Position 80 miles southeast of New Orleans course 340° T. Speed 14K	Checked radar operation targets visible on "Scope" out to 24 miles	442
2-18	0930	In port, New Orleans	In port, New Orleans	443

radar log.

sible for the installation, servicing, and maintenance of ship radar equipment?—The operator or maintenance technician who performs or supervises the above procedures must hold a first-class or second-class radiotelephone or radiotelegraph license with a ship radar endorsement. The only replacements that may be made by a person not so licensed are fuses and receiving-type tubes. (RR 83.164)

6. Who may operate a ship-radar station?—Operation during the course of normal rendition of service must be performed exclusively by the master of the radar-equipped ship or by one or more of the persons responsible to him and authorized by him to do so. (RR 83.164)

7. Under what conditions may a person who does not hold a radio-operator license operate a ship radar station?—Any nonlicensed person may operate the radar provided that the stipulations of RR 83.164 are obeyed. These are: (A) the radar equipment shall employ as its frequency-determining element a nontunable, pulse-type magnetron, (B) the radar equipment shall be capable of being operated with external controls exclusively, in accordance with commission rules and regulations, (C) operation must be by the master or one or more persons responsible to him and authorized by him to do so, and (D) adjustments and tests must be made by properly licensed personnel.

8. Who may make entries in installation and maintenance records of a ship radar station?—The responsible operator concerned. (RR 83.405)

9. What entries are required in the installation and maintenance records of a ship radar station?—These entries are: (A) date and place of initial installation, (B) necesary steps taken to remedy any intereference found to exist at the time of such installation, (C) the nature of any complaint (including interference to radiocommunication) arising subsequent to initial installation and the date thereof, (D) the reason for the trouble leading to the complaint, including the name of any component or component part that failed or was misadjusted, (E) remedial measures taken, and date thereof, (F) the name, license number, and date of the ship-radar endorsement on the first- and second-class operator license of the responsible operator performing or immediately supervising the installation, servicing, or maintenance. See Fig. 15-3. (RR 83.405)

10. Who has the responsibility for making entries in the installation and maintenance record of a ship radar station?—The entries are the responsibility of the operator-licensed installation, service, or maintenance technician concerned in each particular instance, and the station licensee. (RR 83.405)

11. Within what frequency bands do ship radar transmitters operate?—2900 to 3100 MHz, 5460 to 5650 MHz, 9300 to 9500 MHz, and 14 to 14.05 GHz. (RR 83.404)

12. May fuses and receiving-type tubes be replaced in ship radar equipment by a person whose operator's license does not contain a ship-radar endorsement?—Yes. (RR 83.164)

TRANSMITTER AND ANTENNA

13. Describe how a radar beam is formed by a paraboloidal reflector.—The antenna or source of microwave energy is mounted at the focus point of a parabolic reflector. (See Figs. 2-38 and 2-39.) The microwave energy is directed onto the reflecting surface. At this point, it is reflected forward in parallel rays, forming a small-diameter beam. Regardless of the angle of arrival of energy at the reflector from the antenna source, the angle of reflection is such that the rays will be directed in parallel paths.

14. Briefly describe the construction of a waveguide. Why should the interior of the waveguide be clean, smooth, and dry?—Waveguides are constructed of durable weather-resistant metal capable of reflecting microwave energy with a minimum of loss. The cross section of the waveguide is rectangular or tubular (Fig. 2-31 and 2-32). There is no inner conductor and the radio-frequency energy propagates along the waveguide enclosure much as a radio wave is prop-

agated through space. However, it is channeled within the waveguide because of the reflecting inner walls of the guide. These guide walls absorb an insignificant amount of the energy; by suitable dimensioning, they provide an excellent means of guiding a radar pulse from transmitter to antenna, and they also guide a return signal from antenna to receiver input.

The efficiency of the waveguide depends on the uniformity of the inner walls and the completeness with which the waves are reflected from the walls. Therefore, the interior should be clean, smooth, and dry. Water, dust, and corrosion will introduce discontinuities that increase the radio-wave attenuation; if the discontinuity is severe, it may damage some components or seriously affect the range and performance of the radar set.

15. Why are waveguides used in preference to coaxial lines for transmission of microwave energy in most shipboard-radar installations?—Waveguides have much less loss at microwave frequencies than do coaxial lines.

16. Why are rectangular cross-sectional waveguides generally used in preference to circular cross-sectional waveguides?—The rectangular waveguide can more effectively propagate a single excitation mode, and it is less subject to changes in polarization at junctions and bends.

17. Describe how waveguides are terminated at the radar-antenna reflector.—Usually the end of the waveguide is shaped into a horn or some other type of configuration that will direct the microwave energy onto the reflecting surface and provide the most effective transfer of the signal from the guide to a radiated beam of specific horizontal and vertical angles.

18. Why are choke joints often used in preference to flange joints to join sections of a waveguide?—With the use of a choke joint, an electrical short circuit is reflected to the joint. Although the mechanical joint may not be perfect, the electrical continuity is maintained, and there is minimum signal loss at the junction.

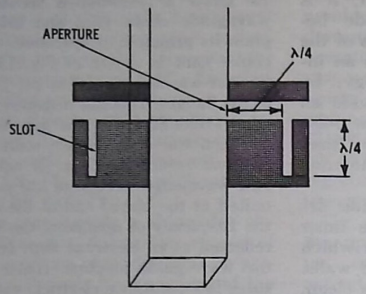
19. Draw a longitudinal section of a waveguide choke joint and briefly explain its principle of operation.—Such a choke joint is shown in Fig. 15-4A. A quarter-wavelength slot is cut into one of the flanges. This slot is spaced a quarter wavelength from the gap, or joint, between the actual inner walls of the two waveguide sections. It acts as a half-wavelength section of line short-circuited at the closed end of the slot. At the frequency of operation, this short is reflected as an electrical short circuit to the wave-guide junction. Hence, it ensures low-resistance electrical continuity even though the mechanical connection between the two sections is not perfect. A choke joint is particularly useful as a rotating joint (Fig. 15-4B).

20. Draw a simple cross-sectional diagram of a magnetron showing anode, cathode, and direction of electron movement under the influence of strong magnetic field.—See Fig. 15-5.

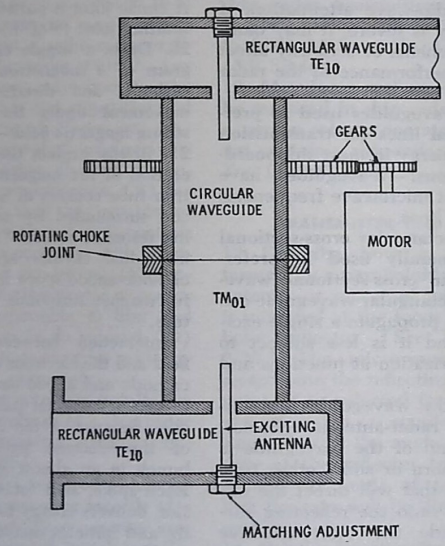
21. Briefly explain the principle of operation of the magnetron.—The magnetron tube consists of a cylindrical cathode surrounded by an anode containing resonant cavities (Fig. 15-5A). The individual cavities are linked to the cathode-anode space by slots. A powerful magnet surrounds the anode structure.

Interaction between the magnetic field and the electrons traveling between cathode and anode causes the electrons to take an angular path toward the anode. Because of the differing velocities of the electron paths, the electrons bunch in an almost spoke-like manner. Each spike, as it rotates across a cavity slot, delivers energy to the resonant cavity and initiates oscillation. In turn, the oscillations of each cavity influence the bunching of electrons, and oscillations are thereby sustained. Output is removed from the magnetron oscillator by inserting a probe into one of the cavities.

22. Why is the anode in the magnetron in a radar transmitter normally maintained at ground potential?—It eliminates the problem of insulating the anode from the chassis, and at the same time, it provides high-voltage protection. The anode-cathode voltage of a magne-



(A) Choke joint.

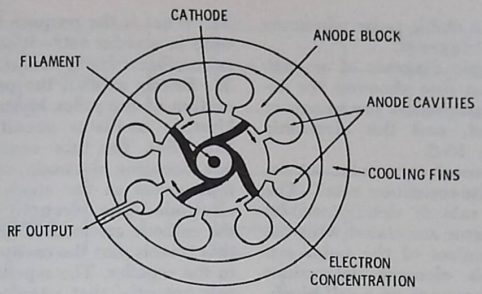


(B) Rotating choke joint.

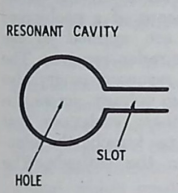
Fig. 15-4. Choke joints.

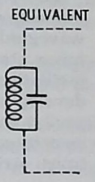
tron is very high. The high operating voltage can be obtained by pulsing the cathode at a high negative potential instead of using a high positive potential on the anode. In so doing, the anode and case of the magnetron can be grounded (Fig. 2-42). Thus there need not be any high potential between the anode and ground which could present insulation problems and a possible shock hazard.

23. What is the peak power of a radar pulse when the pulse width is 1 microsecond, the pulse-repetition rate is 900, and the average power is 18 watts? What is the duty cycle?

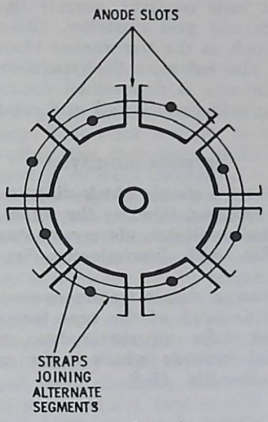


(A) Tube structure.





(B) Anode cavity.



(C) Strapping of anode segments.

Fig. 15-5. Magnetron construction.

$$\text{Peak Power} = \frac{\text{Average Power}}{\text{PRR} \times \text{Duration}}$$

$$= \frac{18}{900 \times 1 \times 10^{-6}} = 20 \text{ kW}$$

$$\text{Duty Cycle} = \frac{\text{Average Power}}{\text{Peak Power}}$$

$$= \frac{18}{20{,}000} = 0.0009$$

24. What is the purpose of the rotary spark gap used in some radar sets?—In older radar sets, a rotary spark gap is used to discharge the pulse network into the load. When its rotating electrode passes a fixed electrode, an arc develops that discharges the line. The rotary gap represents a mechanical means of pulsing a magnetron instead of using an electronic switch, such as a thyratron.

25. What is the purpose of an artificial transmission line in a radar set?—The artificial transmission-line section serves as the pulse network and sets the duration and shape of the radar pulse. It does so with high stability because the pulse is dependent on the characteristics of the line rather than the associated circuit. The charge placed on the line between pulses by a high-voltage source

is discharged as a stable pulse whenever the thyratron is triggered.

26. Draw a simple diagram of an artificial transmission line showing the inductance and capacitance, the source of power, the load, and the electronic switch.—See Fig. 15-6.

27. What component in a radar set determines the pulse-repetition rate?—The pulse-repetition rate is determined by the master oscillator associated with the timer or synchronizer of the radar set.

28. What circuit element determines the operating frequency of a self-blocking oscillator?—The frequency of operation is determined largely by the grid-circuit time constant, namely the grid resistor and grid capacitor. Other factors, such as the transformer characteristics, also influence the repetition rate, but the rate is determined dominantly by the grid resistor and grid capacitor.

RECEIVER-INDICATOR

29. Draw a simple block diagram of a radar receiver, labeling the signal crystal, local oscillator, afc crystal stage, i-f amplifier, and discriminator.—See Fig. 15-7.

30. Draw a simple frequency-converter circuit (mixer) of the type frequently used in radar superheterodyne receivers, and indicate which is the crystal stage.—See Fig. 15-8.

31. What is the purpose of the klystron tube in a radar set?—It serves as the local oscillator for the radar receiver.

32. Briefly explain the principle of operation of the reflex klystron.—A typical klystron oscillator circuit is shown in Fig. 15-9. The tube consists of a cathode, focusing electrode, cavity resonator that serves as the anode, and repeller electrode. The electrons emitted from the cathode are focused into a fine beam that travels past the cavity-resonator gap to the repeller. The repeller has a negative potential that retards the electrons, causing them to return and pass near the cavity gap a second time, but traveling in the opposite direction.

The rf variation that builds up across the cavity gap varies the velocities of the electrons as they move toward the repeller. The electrons bunch together as they leave the gap (they are said to be velocity-modulated). The returned electrons arrive in bunches, and as they pass the gap, they excite the cavity resonant circuit, thus causing it to oscillate.

The strong oscillations in the cavity are removed by means of a probe and waveguide. They are applied to the mixer stage of the radar receiver. The oscillations in the resonant cavity also develop a changing voltage across the cavity gap. It is these variations that velocity-modulate, or bunch, the electrons arriving from the cathode. The

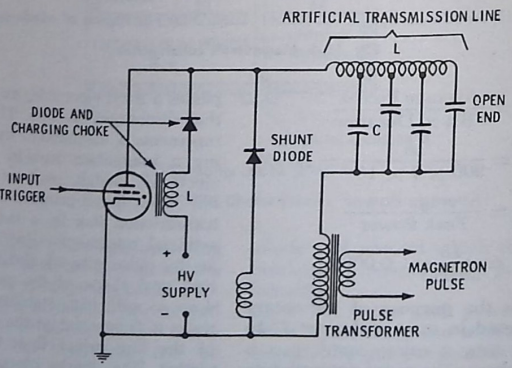


Fig. 15-6. Radar modulator.

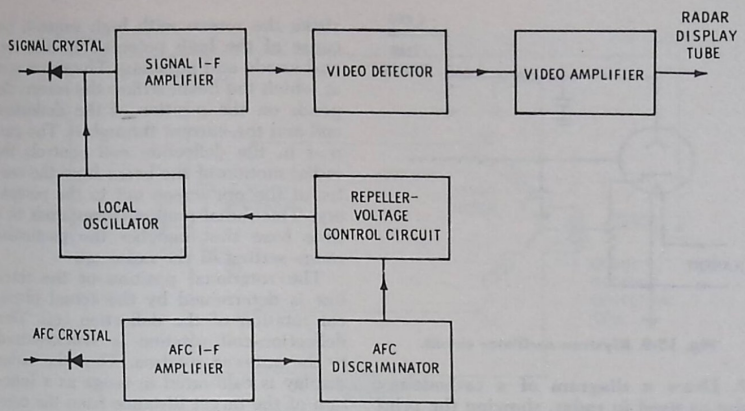


Fig. 15-7. Block diagram of radar receiver.

feedback activity sustains the oscillations.

33. What nominal intermediate frequencies are commonly found in radar receivers?—Commonly they are 30 or 60 MHz, although frequencies as low as 15 MHz and as high as 120 MHz are to be found.

34. What type of detector is frequently used in radar receivers?—The crystal diode is used most frequently.

35. What is the purpose of the discriminator stage in a radar superheterodyne?—The discriminator is a stage in the afc system which applies a frequency-correcting voltage to the radar local oscillator so that incoming signals are converted to a precise intermediate frequency. This error voltage is used in correcting the frequency drift of the magnetron or local oscillator.

36. Briefly explain the purpose of the sensitivity-time control circuit in a radar set.—The sensitivity-time control (stc) circuit lowers the sensitivity of the receiver in receiving nearby target signals. As a result, the return from massive nearby objects and sea return will not be displayed too brightly on the radar screen. Nearby small objects will be displayed more distinctly, and the echoes from more distant targets will not be obscured by an overly bright central area.

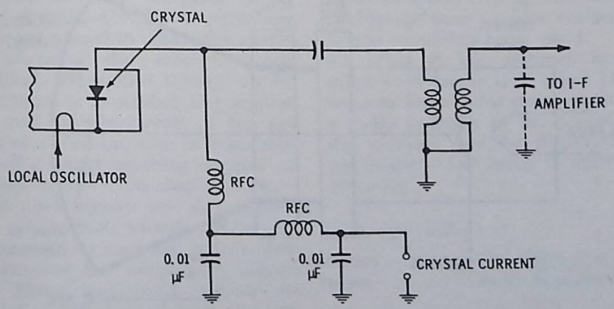


Fig. 15-8. Crystal mixer circuit.

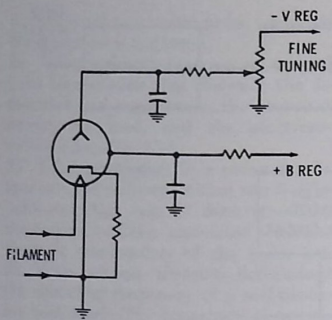


Fig. 15-9. Klystron oscillator circuit.

37. Draw a diagram of a cathode-ray tube as used in radar, showing the principal electrodes in the tube and the path of the electron beam.—See Fig. 15-10.

38. Explain the principle of operation of the cathode-ray ppi tube, and explain the function of each electrode.—In the ppi tube (Fig. 15-10), an electron gun consisting of a cathode, control grid, accelerating grid, and first anode forms the electrons released from the heated cathode into a fine beam. The control grid regulates the intensity of the electron beam, while the difference of potential among the electrodes concentrates, or focuses, the beam. The beam is converged into a fine spot at the surface of the fluorescent screen. The electrons strike the screen with high impact, because of the high potential on the second anode and aquadag. The exact spot at which the beam strikes the screen depends on the position of the deflection coil and the current through it. The current in the deflection coil controls the radial motion of the beam from the center of the ppi screen out to the periphery. This radial motion corresponds to a time base that matches the particular range setting of the radar set.

The rotational position of the trace line is determined by the actual physical rotation of the deflection coil. This deflection-coil rotation is synchronized to the antenna rotation. Thus the radar display is calibrated in range as a function of the target distance from the center, and in bearing as a function of the angular position of the trace line when scanning over the target.

39. What is the purpose of Aquadag coating for cathode-ray tubes?—The coating acts as a part of the second anode to give the final acceleration to the electrons in the crt beam. It provides a conductive coating that also shields the electron-beam deflection from the influence of strong external fields.

40. Draw a simple diagram showing how a synchro generator located in the radar-antenna assembly is connected to a synchro motor, located at the indicator, which rotates the deflection coil.

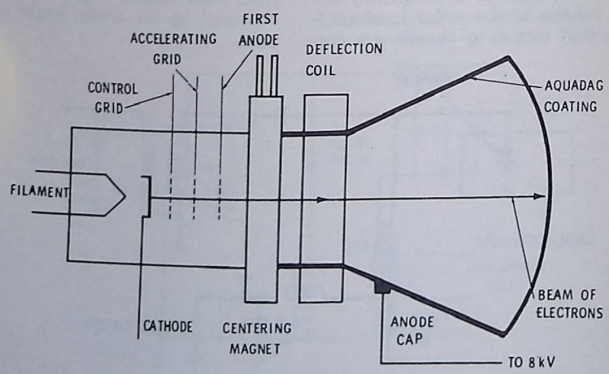


Fig. 15-10. Cathode-ray tube as used in radar set.

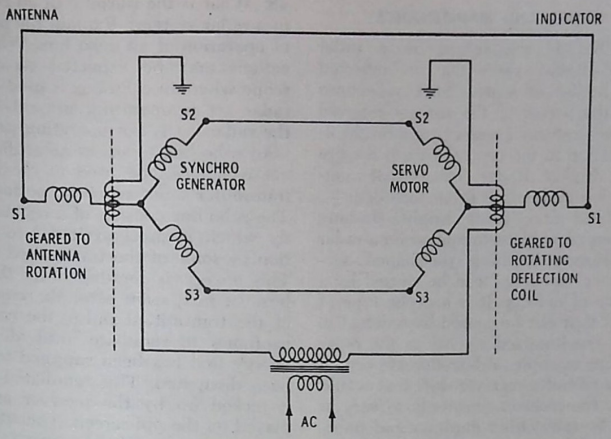


Fig. 15-11. Synchro system for radar set.

Show proper designation of all leads, and show where ac voltages (if needed) are applied.—See Fig. 15-11.

41. What is meant by bearing resolution of a radar set?—Bearing resolution is a measure of the capability of a radar set to delineate between two closely spaced targets at the same range.

42. Explain how heading flash and range-marking circles are produced on a radar ppi scope.—A bright heading flash is reproduced on the radar screen whenever the radar antenna directs its beam dead ahead. Dead ahead refers to the forward direction of travel of the boat or aircraft. Usually a switching arrangement is used in which the switch closes whenever the antenna points dead ahead. When this occurs, an intensifier pulse is generated and applied to the grid-cathode circuit of the ppi tube. It causes an increase in beam current, and a bright marking appears on the screen of the radar display tube.

Range-mark signals are also applied to the grid-cathode circuit of the ppi tube, causing an increase in illumination whenever the range-mark signals arrive. These range-mark signals are generated within the radar set and correspond in their spacing to a specific radar-range travel time. Thus their position on the display tube corresponds to a specific mileage. Although the range-mark signals are in themselves very short-duration pulses, or "pips," they blend together with trace-line rotation to form complete circles on the ppi display. These circles are called range rings.

In the range-mark generator, a series of sine waves is formed under control of a timing-gate pulse. These sine waves are squared and differentiated, forming very sharp signal spikes. The separation between spikes corresponds to a specific calibration time (1-mile excursion time, 5-mile excursion time, etc.).

43. What is the distance in nautical miles to a target if it takes 123 microseconds for a radar pulse to travel from a radar antenna to the target, back to the antenna and be displayed on the ppi scope?—The range is approximately 10 miles.

$$\text{Range (miles)} = \frac{\text{Total Time in } \mu\text{ Seconds}}{\text{Velocity in } \mu\text{ Seconds/Mile}}$$

$$= \frac{123}{12.3} = 10 \text{ miles}$$

RADAR AND MAINTENANCE

44. What is sea return on a radar scope?—Radar waves that are reflected from bodies of water. Such reflections from the waves of the sea are referred to as sea return. These cause a bright illumination in the central area of the ppi radar display. Radar circuits that minimize sea clutter are often included.

45. What may cause bright, flashing pie-shaped sections to appear on a radar ppi scope?—Flashing pie-shaped sections, or "spoking," can be caused by a variety of defects. It is a cyclic type of defect that can be caused by a defect in some synchronized activity in the radar set. For example, a defective afc crystal could permit a receiver drift that would cause the receiver sensitivity to vary at a cyclic rate. Other duplexer and transmitter defects can cause a similar disturbance. Servo defects and loss of synchronism between antenna rotation and trace-line rotation may cause a similar defect.

46. What precaution should a radar serviceman observe to prevent personal injury to himself or other persons when making repairs or adjustments to a radar set?—Radar sets operate at high power and with high voltage. High voltages are always a hazard; power should be shut off and high-voltage capacitors should be discharged with a grounding stick before you work inside a set. If power-on work must be done, it should be performed carefully and with someone nearby who can turn off the equipment quickly if need be. Be careful not to draw arcs when making on-site checks in the presence of gasoline or battery fumes. Employ the usual precautions in handling the special radar tubes. A radar display tube, like any crt, is subject to implosion.

47. Is there any danger in testing or operating radar equipment aboard ship when explosives or inflammable cargo is being handled?—Yes, because radar sets employ high voltages which have a tendency to arc. Furthermore, the concentrated power in a signal from a high-power radar set is capable of overheating certain flammable materials.

48. What is the purpose of an echo box in a radar system? Explain the principle of operation of an echo box. What indications may be expected on a radar scope when an echo box is used and the radar set is operating properly? when the radar set is not operating properly?—An echo box serves as an artificial target which can be used to check radar transmitter and receiver performance. The echo box consists of a resonant cavity which is shock-excited into oscillation by some of the transmitted energy. This energy is reradiated by the echo box. In fact, even after the conclusion of the transmitted pulse, the echo box continues to reradiate until all of the energy that has been supplied to it has been dissipated. This reradiated energy is picked up by the receiver and displayed on the ppi screen. Thus the echo box acts as an artificial target.

The length and shape of the spoke pattern displayed becomes an indicator or radar-system performance. A decrease in the spoke length or any other distortion of its shape as compared to past results indicates improper operation.

49. What effect, if any, does the accumulation of soot or dirt on the antenna reflector have on the operation of a ship radar?—A thin accumulation has very little influence; excessive amounts may cause some deterioration of performance. The higher the frequency of operation and the sharper the desired beam, the more adverse will be the influence of an excessive accumulation. Most modern radars include a plastic radome which protects the installation from dirt and weather, thus extending the life of moving parts and providing more effective isolation of the antenna and waveguide from the ill effects of moisture, dirt, etc.

50. In a radar set, what are the indications of (A) a defective magnetron, (B) a weak magnet in the magnetron?—A defective magnetron is indicated by an improper magnetron current or absent, weak, or fuzzy target presentations on the screen. Noise and range marks will appear normal. Protective relays may drop out, and there may be some modulator arcing.

A weak magnet causes an increase in magnetron current. There may be a low output, a change in frequency, or a change in the spectrum distribution of the transmitted pulse.

51. What symptoms on a radar scope would indicate that the radar-receiver mixer crystal is defective?—Target signals would be absent, weak, or fuzzy. The noise level would be higher than normal. An echo-box test would show a decline in receiver sensitivity.

52. What care should be taken when handling silicon crystal-rectifier cartridges for replacement in radar superheterodyne receivers?—The radar-receiver crystals are sensitive to very weak signals and can be damaged by the application of above-rating voltages, whether from a static charge or an excessive test-meter voltage or current.

53. What precautions should a radar serviceman take when working with or handling a magnetron?—The magnetron should not be jarred or struck sharply, and it should be handled with the same care with which you would service any delicate electronic component. The magnet should not be overheated or struck sharply.

54. What precautions should the service and maintenance operator observe when replacing the cathode-ray tube in a radar set?—The power should be off and high-voltage capacitor charges drained off. A wise precaution is the use of gloves and goggles. As in the handling of any cathode-ray tube, the strain should be placed on the screen end rather than the neck of the tube.

55. Name at least four pieces of radio or electronic equipment aboard ship which might suffer interference from radar equipment.—Communications receivers, radiotelephone and radiotelegraph equipment, df (direction finder), loran (long-range navigation) equipment and intercommunication facilities.

56. Why is it important that all units of a radar installation be thoroughly bonded to the ship's electrical ground?—Radar sets operate at high power, and furthermore, they generate high-powered short-duration pulses. The magnitude and number of harmonic pulse components are great. Consequently, the set must be well grounded to minimize the radiation or transmission along the power lines of these components. Proper grounding of high-powered equipment is also necessary in the reduction of shock hazards and other annoying voltage buildups.

57. Describe how various types of interference from a radar installation may be apparent to a person when listening to a radiocommunications receiver.—Several types of interference can originate at a radar set. Because so many harmonics are generated, it is possible to hear herterodynes, or "birdies," at various points as you tune over the frequency spectrum of the communications receiver. Often these heterodynes are spaced at regular intervals over a given frequency spectrum because of their harmonic relation. A tone or a steady hash can be picked up because the pulse-repetition rate itself is in the audible range. Other sources of noise are motors, generators, and power-circuit components.

58. Briefly explain why radar interference to a radiotelephone receiver is often characterized by a steady tone in the radio speaker.—The pulses generated in a radar set are in the audible frequency range. Therefore, in cases of interference it is the modulation which occurs at the pulse-repetition rate that is heard.

59. At what frequencies should the radar serviceman look for radar interference on ships equipped with radar?—The harmonic content of the high-powered short-duration pulses is such that interference components can be spread over a considerable frequency spectrum. However, of primary importance are those frequencies used by the particular shipboard station. Thus, it is wise to tune over each of the frequency bands assigned to the marine service. Direction-finding and radiotelegraph assignments are made at various segments of the spectrum between 100 and 515 kHz. Loran and marine radiotelephone assignments are in the frequency spectrum between 1.8 and 3 MHz. Long-distance marine communications are assigned

spot-frequency bands between 3 and 30 MHz. There are also vhf-band harbor radio assignments.

60. Is there any likelihood that a radar installation will cause interference to radio receivers if long connecting lines are used between the radar transmitter and the radar modulator?—Yes, particularly if the lines are not shielded or properly terminated. The modulator pulse is of high magnitude and is rich in harmonics; it can be a definite source of interference. It is preferable to use as short a length of line as possible between the modulator and transmitter.

61. How are the various types of radar interference recognized in (A) autoalarm equipment, (B) direction-finding equipment?—Listening checks are made. Heterodynes and audible tones are likely to be heard when interference is present. Autoalarm sets include a monitor jack into which you can insert a headset for listening purposes.

62. In checking a direction finder interference caused by radar equipment, would it be a good policy to check for interference while the df loop is being rotated?—This might be a good method to isolate the source of interference. You can determine whether the interference is coming from the radar set of a nearby vessel or the radar set under test. It might also help in determining whether the interference is being coupled over the common power circuits of the vessel or by direct radiation from the modulator-transmitter.

63. What steps might be taken by a radar serviceman to eliminate a steady-tone type of interference to radiocommunication receivers or interference to loran receivers evidenced by spike?—Of principal concern are shielding and proper termination of pulse lines. Both the receiving equipment of concern and the radar equipment should be grounded and bonded. Power circuits at both systems should include rf filters because of the high-frequency distribution of the pulse harmonics. A final step may be to try additional physical separation between systems.

64. What steps might be taken by a radar serviceman to reduce grass on a loran scope or motor-generator noise in a communications receiver?—Shielding, bonding of units together, and grounding are of principal concern. Motors and generators should be filtered where possible, and appropriate filters should be installed in the power line. All types of sparking interference should be eliminated, and commutators and brushes must be kept in good condition.

65. List at least two types of indications on a loran scope that signify that a radar installation is causing interference to the loran.—There is a high noise level as made apparent by grass near the sweep line. Strong pulse components from the radar will cause spikes to move right or left across the loran display tube.

66. What considerations should be taken into account when selecting the location of the radar-antenna assembly aboard ship?—The antenna should be mounted in the clear and spaced as far as is practical from obstacles that might influence the antenna pattern or produce obscuring patterns on the radar screen. In some installations, obstructions are unavoidable, and if obstructions are present, the antenna should be mounted so that they are to the rear of the antenna.

To minimize attenuation, the waveguide span should be kept as short as is practical. The radar-antenna system must be well supported physically so that it can readily withstand environmental extremes.

67. In the installation of waveguides, why should long, perfectly level sections of waveguide be avoided? Why is a small hole about ⅛ inch in diameter drilled on the underside of an elbow in a waveguide near the point where it enters the radar transmitter?—Moisture content in the line must be kept at a minimum to prevent discontinuities and resultant attenuation. Moisture must be kept from the duplexer and transmitter-receiver to prevent poor performance and possible equipment damage. Thus, a drain hole or absorbent material is inserted near the entrance point. Long, perfectly level runs are to be avoided, because they are especially prone to an

accumulation of moisture that does not drain off quickly.

68. To prevent moisture from entering the waveguide, what precautions should be taken when installing vertical sections of waveguide with choke-coupling flanges?—A good vertical mounting should be made so as to minimize the collection of moisture. Gaskets can be used to ensure a more weatherproof joint.

APPENDIX

Extracts From the Communications Act of 1934, As Amended; International Telecommunication Convention, Atlantic City, 1947; International Radio Regulations (Atlantic City, 1947) Telegraph Regulations (Paris Revision, 1949)

EXTRACTS FROM THE COMMUNICATIONS ACT OF 1934, AS AMENDED

SEC. 1. For the purpose of regulating interstate and foreign commerce in communication by wire and radio so as to make available, so far as possible, to all the people of the United States a rapid, efficient, Nation-wide, and worldwide wire and radio communication service with adequate facilities at reasonable charges, for the purpose of the national defense, for the purpose of promoting safety of life and property through the use of wire and radio communication, and for the purpose of securing a more effective execution of this policy by centralizing authority heretofore granted by law to several agencies and by granting additional authority with respect to interstate and foreign commerce in wire and radio communication, there is hereby created a Commission to be known as the "Federal Communications Commission," which shall be constituted as hereinafter provided and which shall execute and enforce the provisions of this act.

* * * * * * *

SEC. 301. It is the purpose of this Act, among other things, to maintain the control of the United States over all the channels of interstate and foreign radio transmission; and to provide for the use of such channels, but not the ownership thereof, by persons for limited periods of time, under licenses granted by Federal authority, and no such license shall be construed to create any right, beyond the terms, conditions, and periods of the license. No person shall use or operate any apparatus for the transmission of energy or communications or signals by radio (a) from one place in any Territory or possession of the United States or in the District

of Columbia to another place in the same Territory, possession, or district; or (b) from any State, Territory, or possession of the United States, or from the District of Columbia to any other State, Territory, or possession of the United States; or (c) from any place in any State, Territory, or possession of the United States, or in the District of Columbia, to any place in any foreign country or to any vessel; or (d) within any State when the effects of such use extend beyond the borders of said State, or when interference is caused by such use or operation with the transmission of such energy, communications, or signals from within said State to any place beyond its borders, or from any place beyond its borders to any place within said State, or with the transmission or reception of such energy, communications, or signals from and/or to places beyond the borders of said State; or (e) upon any vessel or aircraft of the United States; or (f) upon any other mobile stations within the jurisdiction of the United States, except under and in accordance with this Act and with a license in that behalf granted under the provision of this Act.

* * * * * * *

SEC. 303. Except as otherwise provided in this Act, the Commission from time to time, as public convenience, interest, or necessity requires, shall—

* * * * * * *

(m) (1) Have authority to suspend the license of any operator upon proo sufficient to satisfy the Commission that the licensee—

(A) Has violated any provision of any Act, treaty, or convention binding o the United States which the Commission is authorized to administer, or any regulation made by the Commission under any such Act, treaty, or convention; or

(B) Has failed to carry out a lawful order of the master or person lawfully in charge of the ship or aircraft on which he is employed; or

(C) Has willfully damaged or permitted radio apparatus or installations to be damaged; or

(D) Has transmitted superfluous radio communications or signals or communications containing profane or obscene words, language, or meaning, or has knowingly transmitted—

(1) False or deceptive signals or communications, or

(2) A call signal or letter which has not been assigned by proper authority to the station he is operating; or

(E) Has willfully or maliciously interfered with any other radio communications or signals; or

(F) Has obtained or attempted to obtain, or has assisted another to obtain or attempt to obtain, an operator's license by fraudulent means.

(2) No order of suspension of any operator's license shall take effect until fifteen days' notice in writing thereof, stating the cause for the proposed suspension, has been given to the operator licensee who may make written application to the Commission at any time within said fifteen days for a hearing upon such order. The notice to the operator licensee shall not be effective until actually received by him, and from that time he shall have fifteen days in which to mail the said application. In the event that physical conditions prevent mailing of the application at the expiration of the fifteen-day period, the application shall then be mailed as soon as possible thereafter, accompanied by a satisfactory explanation of the delay. Upon receipt by the Commission of such application for hearing, said order of suspension shall be held in abeyance until the conclusion of the hearing which shall be conducted under such rules as the Commission may prescribe. Upon the conclusion of said hearing the Commission may affirm, modify, or revoke said order of suspension.

(n) Have authority to inspect all radio installations associated with stations required to be licensed by any Act or which are subject to the provisions of any

Act, treaty, or convention binding on the United States, to ascertain whether in construction, installation, and operation they conform to the requirements of the rules and regulations of the Commission, the provisions of any Act, the terms of any treaty or convention binding on the United States, and the conditions of the license or other instrument of authorization under which they are constructed, installed, or operated.

* * * * * * *

SEC. 318. The actual operation of all transmitting apparatus in any radio station for which a station license is required by this Act shall be carried on only by a person holding an operator's license issued hereunder, and no person shall operate any such apparatus in such station except under and in accordance with an operator's license issued to him by the Commission: *Provided, however,* That the Commission if it shall find that the public interest, convenience, or necessity will be served thereby may waive or modify the foregoing provisions of this section for the operation of any station except (1) stations for which licensed operators are required by international agreement, (2) stations for which licensed operators are required for safety purposes, (3) stations engaged in broadcasting and (4) stations operated as common carriers on frequencies below thirty thousand kilohertz: *Provided further,* That the Commission shall have power to make special regulations governing the granting of licenses for the use of automatic radio devices and for the operation of such devices.

* * * * * * *

SEC. 325. (a) No person within the jurisdiction of the United States shall knowingly utter or transmit, or cause to be uttered or transmitted, any false or fraudulent signal of distress, or communication relating thereto, nor shall any broadcasting station rebroadcast the program or any part thereof of another broadcasting station without the express authority of the originating station.

* * * * * * *

SEC. 326. Nothing in this Act shall be understood or construed to give the Commission the power of censorship over the radio communications or signals transmitted by any radio station, and no regulation or condition shall be promulgated or fixed by the Commission which shall interfere with the right of free speech by means of radio communication.*

* * * * * * *

SEC. 501. Any person who willfully and knowingly does or causes or suffers to be done any act, matter, or thing, in this Act prohibited or declared to be unlawful, or who willfully or knowingly omits or fails to do any act, matter, or thing in this Act required to be done, or willfully and knowingly causes or suffers such omission or failure, shall, upon conviction thereof, be punished for such offense, for which no penalty (other than a forfeiture) is provided in this Act, by a

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*The last sentence of Sec. 326 was repealed and recodified as § 1464 of the Criminal Code 18 U. S. C. 1464 by "An Act to revise, codify and enact into positive law title 18 of the United States Code, entitled 'Crimes and Criminal Procedure' ", Public No. 772, 80th Cong. 2nd Session, approved June 25, 1948, effective September 1, 1948. The last sentence of Section 326 was as follows: *"No person within the jurisdiction of the United States shall utter any obscene, indecent, or profane language, by means of radio communication".*

§ 1464, Public No. 772, 80 Cong. 2nd Session reads as follows: § 1464. Broadcasting Obscene Language. Whoever utters any obscene, indecent, or profane language by means of radio communication shall be fined not more than $10,000 or imprisoned not more than two years or both."

fine of not more than $10,000 or by imprisonment for a term not exceeding one year, or both; except that any person, having been once convicted of an offense punishable under this section, who is subsequently convicted of violating any provision of this Act punishable under this section, shall be punished by a fine of not more than $10,000 or by imprisonment for a term not exceeding two years, or both.

SEC. 502. Any person who willfully and knowingly violates any rule, regulation, restriction, or condition made or imposed by the Commission under authority of this Act, or any rule, regulation, restriction, or condition made or imposed by any international radio or wire communications treaty or convention, or regulations annexed thereto, to which the United States is or may hereafter become a party, shall, in addition to any other penalties provided by law, be punished, upon conviction thereof, by a fine of not more than $500 for each and every day during which such offense occurs.

* * * * * * *

SEC. 605. No person receiving or assisting in receiving, or transmitting, or assisting in transmitting, any interstate or foreign communication by wire or radio shall divulge or publish the existence, contents, substance, purport, effect, or meaning thereof, except through authorized channels of transmission or reception to any person other than the addressee, his agent, or attorney, or to a person employed or authorized to forward such communication to its destination, or to proper accounting or distributing officers of the various communicating centers over which the communication may be passed, or to the master of a ship under whom he is serving, or in response to a subpena issued by a court of competent jurisdiction, or on demand of other lawful authority; and no person not being authorized by the sender shall intercept any commmunication and divulge or publish the existence, contents, substance, purport, effect or meaning of such intercepted communication to any person; and no person not being entitled thereto shall receive or assist in receiving any interstate or foreign communication by wire or radio and use the same or any information therein contained for his own benefit or for the benefit of another not entitled thereto; and no person having received such intercepted communication or having become acquainted with the contents, substance, purport, effect, or meaning of the same or any part thereof, knowing that such information was so obtained, shall divulge or publish the existence, contents, substance, purport, effect, or meaning of the same or any part thereof, or use the same or any information therein contained for his own benefit or for the benefit of another not entitled thereto: *Provided:* That this section shall not apply to the receiving, divulging, publishing, or utilizing the contents of any radio communication broadcast, or transmitted by amateurs or others for the use of the general public, or relating to ships in distress.

EXTRACTS FROM THE INTERNATIONAL TELECOMMUNICATION CONVENTION, ATLANTIC CITY, 1947

Article 32

1. Members and Associated Members agree to take all possible measures, compatible with the system of telecommunication used, with a view to insuring the secrecy of international correspondence.

* * * * * * *

Article 43

1. Stations performing radio communication in the mobile service shall be bound, within the limits of their normal employment, to exchange radiocommunications reciprocally without distinction as to the radio system adopted by them.

* * * * * * *

Article 44

1. All stations, whatever their purpose, must be established and operated in such a manner as not to result in harmful interference to the radio services or communications of other Members or Associate Members or of recognized private operating agencies, or of other duly authorized operating agencies which carry on radio service, and which operate in accordance with the provisions of the Radio Regulations.

° ° ° ° ° ° °

Article 45

1. Radio stations shall be obligated to accept, with absolute priority, distress calls and messages regardless of their origin, to reply in the same manner to such messages, and immediately to take such action in regard thereto as may be required.

° ° ° ° ° ° °

Article 46

Members and Associate Members agree to take the steps required to prevent the transmission or circulation of false or deceptive distress or safety signals and the use, by a station, of call signs which have not been regularly assigned to it.

EXTRACTS FROM THE INTERNATIONAL RADIO REGULATIONS ANNEXED TO THE INTERNATIONAL TELECOMMUNICATIONS CONVENTION, ATLANTIC CITY, 1947

Article 13

372 SEC. 1. Unnecessary transmissions and transmission of superfluous signals and correspondence are forbidden to all stations.

° ° ° ° ° ° °

383 SEC. 9. The transmission of signals without identification is forbidden to all stations.

° ° ° ° ° ° °

Article 19

420 SEC. 5. Call signs in the international series are formed as stated below. It is understood, however, that in accordance with the table in 419, the first letter in certain series is replaced by a digit:

° ° ° ° ° ° °

424 (d) Five letters in the case of aircraft stations (for aircraft stations using radiotelephony see 431.)

° ° ° ° ° ° °

431 SEC. 6. (4) Aircraft stations using radiotelephony may use as a call sign:
—a call sign established in conformity with 424;
—a combination of characters corresponding to the official registration mark assigned to the aircraft.

° ° ° ° ° ° °

Article 29

610 SEC. 6.(1) Before emitting, every station must listen for a period long enough to satisfy itself that it will not cause harmful interference to transmissions in

progress within its range; if such interference is likely, the station awaits the first break in the transmission with which it might interfere.

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649 SEC. 15. *Difficulties in reception.*

650 (1) If the station called is prevented from receiving, it replies to the call as indicated in 636, but it replaces the letter K by the signal · — · · · (wait), followed by a number indicating in minutes the probable duration of the waiting time. If the probable duration exceeds 10 minutes (5 minutes in the case of aircraft stations communicating with stations of the maritime mobile service), the reason for the delay must be given.

651 (2) When a station receives a call without being certain that such a call is intended for it, it must not reply until the call has been repeated and understood. When, on the other hand, a station receives a call which is intended for it, but is uncertain of the call sign of the calling station, it must reply immediately, using the service abbreviation in place of the call sign of this latter station.

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679 SEC. 26. Where it is necessary for a mobile station to send signals for testing or adjustment which are liable to interfere with the working of a neighboring coast or aeronautical station, the consent of the station must be obtained before such signals are sent.

680 SEC. 27. When it is necessary for a station in the mobile service to make test signals, either for the adjustment of a transmitter before making a call or for the adjustment of a receiver, they must not continue for more than 10 seconds and must be composed of a series of VVV followed by the call sign of the station emitting the test signals.

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Article 31

704 SEC. 1. Two types of calling signal "To all stations" are recognized:

705 (a) Call CQ followed by the letter K (see 707 and 708);

706 (b) Call CQ not followed by the letter K (see 709).

707 SEC. 2. Stations desiring to enter into communication with stations of the mobile service, without, however, knowing the names of any such stations within their range of action, may use the enquiry signal CQ, in place of the call sign of the station called in the calling formula, the call being followed by the letter K (general call to all stations in the mobile service with request for reply).

708 SEC. 3. In the maritime mobile service, in regions where traffic is congested, the use of the call CQ followed by the letter K is forbidden. As an exception it may be used with signals denoting urgency.

709 SEC. 4. The call CQ not followed by the letter K (general call to all stations without request for reply) is used before the transmission of information of any kind intended to be read or used by anyone who can intercept it.

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Article 33

733 SEC. 9. (1) In order to increase the safety of life at sea and over the sea, all stations of the maritime mobile service normally keeping watch on frequencies in the authorized bands between 405 and 535 kc/s must, during their hours of service, take the necessary measures to ensure watch on the international distress frequency 500 kHz for three minutes twice an hour beginning at x h 15 and x h 45, Greenwich mean time (G. M. T.).

734 (2) During the periods mentioned above, except for the emission provided for in article 37 (see 934 to 949):

735 (a) Transmissions must cease within the bands 485 to 515 kHz;

736 (b) Outside this band, transmissions of stations of the mobile service may continue; stations of the maritime mobile service may listen to these transmissions on the express conditions that they first ensure watch on the distress frequency as provided by 733.

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Article 34

811 SEC. 6. As far as is reasonable and practicable, the provisions concerning the radiotelegraph service relating to:

—procedure (article 29).
—calling (article 30),
—distress urgency and safety signals (article 37).
and
—conditions of closure of the service (article 35),

are applicable to the maritime mobile radiotelephone service.

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815 SEC. 9. (1) The frequency 2182 kHz may be used for calls and replies, and it is the frequency to be used for the distress call and traffic, as well as for urgency and safety signals and messages.

816 (2) Its use for call and reply purposes between ship and coast stations is permitted only within the service areas of coast stations duly authorized by their administrations to this effect after a special arrangement if necessary. This information shall be indicated in the list of Coast and Ship Stations.

817 (3) However, an administration may assign to a station other frequencies for call and reply.

818 (4) The distress signal in radiotelephony is defined in 873.

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Article 35

852 SEC. 11. (1) Ship stations whose service is not continuous may not close before:

853 (a) Finishing all operations resulting from a distress call, urgency or safety signal;

854 (b) Exchanging so far as practicable all traffic originating in or destined for coast stations situated within their range and mobile stations which being within their range, have indicated their presence before the actual cessation of work.

855 (2) Any ship station not having fixed working hours must inform the coast stations, with which it is in communication, of the time of closing and the time of reopening its service.

856 SEC. 12. (1) (a) Any mobile station arriving in port, and whose service is therefore about to close, must so notify the nearest coast station and, if necessary, the other coast stations with which it generally communicates.

857 (b) It must not close until after the disposal of traffic on hand, unless the regulations in force in the country where it is calling do not permit this.

858 (2) Upon departure from port the mobile station must notify the coast station or stations concerned that its service is reopening from the moment when such reopening is permitted by the regulations in force in the country where the port of departure is situated.

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Article 37

866 SEC. 3. (1) The speed of telegraph transmission in cases of distress, urgency or safety must not in general exceed 16 words a minute.

867 (2) The speed of transmission for the alarm signal is indicated in 920.

868 SEC. 4. Ships.

(1) In case of distress, the frequency to be used shall be the international distress frequency, that is, 500 kHz; it must preferably be used on class A2 or B emissions.

869 (2) In case of distress for radiotelephone stations working in the authorized bands between 1605 and 2850 kHz, the frequency to be used is the distress frequency 2182 kHz (see article 34 and particularly 815).

870 (3) Ship stations which cannot transmit on the above distress frequencies shall use their normal calling frequency.

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872 SEC. 6. (1) In radiotelegraphy, the distress signal consists of the group · · · — — — · · · transmitted as a single signal in which the dashes must be emphasized so as to be distinguished clearly from the dots.

873 (2) In radiotelephony, the distress signal consists of the word MAYDAY pronounced as the French expression "m'aider."

874 SEC. 7. These distress signals indicate that the ship, aircraft, or other vehicle sending the distress signal is threatened by grave and imminent danger and requests immediate assistance.

875 SEC. 8. The distress call and message are sent only on the authority of the master or person responsible for the ship, aircraft or other vehicle carrying the mobile station.

876 SEC. 9. (1) The distress call, when sent by radiotelegraphy on 500 kHz is, as a general rule, preceded by the alarm signal as defined in 920.

877 (2) When circumstances permit, the transmission of the call is separated from the end of the alarm signal by an interval of two minutes. In this case, the alarm signal must be followed immediately by the distress signal · · · — — — · · · sent three times, in order to operate the automatic apparatus mentioned in 931.

878 SEC. 10. The distress call sent by radiotelegraphy comprises:

—the distress signal transmitted three times;
—the word DE;
—the call sign of the mobile station in distress, sent three times.

879 SEC. 11. The distress call, when sent by radiotelephony, is generally preceded by the signal · · · — — — · · · produced by a whistle or any other suitable means.

880 SEC. 12. The distress call sent by radiotelephony comprises:

—the distress signal MAYDAY spoken three times;
—the words THIS IS, followed by the identification of the mobile station in distress, the whole repeated three times.

881 SEC. 13. The distress call has absolute priority over other transmissions. All stations which hear it must immediately cease any transmission capable of interfering with the distress traffic and must listen on the frequency used for the emission of the distress call. This call must not be addressed to a particular station and acknowledgement of receipt is not to be given before the distress message is sent.

882 SEC. 14. (1) The distress call must be followed as soon as possible by the distress message. This message comprises:

—the distress call;
—the name of the ship, aircraft, or vehicle in distress;
—particulars of its position, the nature of the distress and the kind of assistance desired;
—any other information which might facilitate the rescue.

883 (2) As a general rule, a ship signals its position in latitude and longitude (Greenwich), using figures for the degrees and minutes, together with one of the words NORTH or SOUTH and one of the words EAST or WEST. The signal · — · — · — is used to separate the degrees from the minutes. When practicable, the true bearing and distance in nautical miles from a known geographical point may be given.

884 (3) As a general rule, and if time permits, an aircraft shall transmit in its distress message the following information:

—estimated position and time of the estimate;
—true heading and indicated air speed;
—altitude;
—type of aircraft;
—nature of distress;
—intention of person in command (such as forced alighting on the sea or crash landing).

885 (4) As a general rule, an aircraft in flight signals its position:

—if possible by latitude and longitude (Greenwich), using figures for the degrees and minutes, together with one of the words NORTH or SOUTH and one of the words EAST or WEST; or
—By the name of the nearest place, and its approximate distance in relation thereto, together with one of the words NORTH, SOUTH, EAST, or WEST, as the case may be, or, when practicable, by words indicating intermediate directions.

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887 Sec. 16. (1) The distress message must be repeated at intervals, especially during the period of silence prescribed in 733, until an answer is received.

888 (2) The alarm signal may also be repeated, if necessary.

889 (3) The intervals must, however, be sufficiently long to allow time for stations preparing to reply to start their sending apparatus.

890 (4) When the mobile station in distress receives no answer to a distress message sent on a distress frequency, the message may be repeated on any other available frequency on which attention might be attracted.

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892 Sec. 18. A mobile station which learns that another mobile station is in distress may transmit the distress message in either of the following cases:

893 (a) The station in distress is not itself in a position to transmit it;

894 (b) The master or person responsible for the ship, aircraft or other vehicle carrying the station which intervenes, believes that further help is necessary.

895 Sec. 19. (1) Stations of the mobile service which receive a distress message from a mobile station which is, beyond any possible doubt, in their vicinity, must immediately acknowledge receipt (see 913, 914 and 915). If the distress call has not been preceded by the alarm signal, these stations may transmit this alarm signal with the permission of the authority responsible for the station, taking care not to interfere with the transmission of acknowledgments of receipt sent by other stations.

896 (2) Stations of the mobile service which receive a distress message from a mobile station which, beyond any possible doubt, is not in their vicinity, must allow a short interval of time before acknowledging receipt of the message, in order to permit stations nearer to the mobile station in distress to answer and acknowledge receipt without interference.

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898 SEC. 20. Distress traffic comprises all messages relative to the immediate assistance required by the mobile station in distress.

899 SEC. 21. In distress traffic, the distress signal must be sent before the call and at the beginning of the preamble of any radiotelegram.

900 SEC. 22. The control of distress traffic is the responsibility of the mobile station in distress or of the mobile station which, by the application of the provisions of 892 and 893, has sent the distress call. These stations may, however, delegate the control of the distress traffic to another station.

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904. SEC. 24. (1) Any station which hears a distress call must comply with the provisions of 881.

905 (2) Any station of the mobile service which has knowledge of distress traffic must follow such traffic, even if it does not take part in it.

906 (3) For the entire duration of distress traffic, it is forbidden for all stations which are aware of this traffic and which are not taking part in it:

907 (a) To transmit on the frequencies on which the distress traffic is taking place;

908 (b) To use class B emissions.

909 (4) A station of the mobile service which, while following distress traffic, is able to continue its normal service, may do so when the distress traffic is well established and on condition that it observes the provisions of 906, 907 and 908 and does not interfere with the distress traffic.

910 SEC. 25. A land station receiving a distress message must without delay take the necessary action to advise the authorities participating in the operation of rescue facilities.

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913 SEC. 27. The acknowledgment of receipt of a distress message is given in the following form:

—call sign of the mobile station in distress (three times);
—the word DE;
—call sign of the station acknowledging receipt (three times);
—group RRR;
—distress signal.

914 SEC. 28. (1) Every mobile station which acknowledges receipt of a distress message must, on the order of the master or person responsible for the ship, aircraft or other vehicle, transmit, as soon as posssible, the following information in the order shown:

—its name;
—its position in the form prescribed in 883 and 885;
—the speed at which it is proceeding towards the ship, aircraft or other vehicle in distress.

915 (2) Before sending this message, the station must ensure that it will not interfere with the emissions of other stations better situated to render immediate assistance to the station in distress.

916 SEC. 29. (1) Any station of the mobile service which is not in a position to render assistance and which has heard a distress message which has not been immediately acknowledged, must take all possible steps to attract the attention of stations of the mobile service which are in a position to render assistance.

917 (2) For this purpose, with the approval of the authority responsibile for the station, the distress call or the distress message may be repeated. This repetition is made on full power either on the distress frequency or on one of the frequencies which may be used in case of distress (see 868 to 871). At the same time all necessary steps are taken to notify the authorities who may be able to intervene usefully.

918. (3) In radiotelegraphy, the repetition of the distress call or distress message is generally preceded by the transmission of the alarm signal as defined in 920. A sufficient interval of time is to be allowed between the transmission of an alarm signal and the repetition of the distress call or distress message, so that mobile stations, which do not keep continuous watch and which are warned by the sounding of their automatic alarm apparatus, have time to go on watch.

919 (4) A station which repeats a distress call or distress message, follows it by the word DE and its own call sign transmitted three times.

920 SEC. 30. (1) The alarm signal shall consist of a series of twelve dashes sent in one minute, the duration of each dash being four seconds and the duration of the interval between two consecutive dashes one second. It may be transmitted by hand but its transmission by means of an automatic instrument is recommended.

921 (2) Any ship station working in the band 405 to 535 kHz which is not provided with an automatic apparatus for the transmission of the alarm signal, must be permanently equipped with a clock, clearly marking the seconds, preferably by means of a sweep hand completing one revolution per minute. This clock must be placed at a point sufficiently visible from the operator's table in order that the operator may, by keeping it in view, easily and correctly time the different elements of the alarm signal.

922 (3) This special signal has for its sole purpose the actuation of the automatic devices giving the alarm. It must be used solely either to announce that a distress call or message is about to follow or to announce the transmission of an urgent cyclone warning; in the latter case it may be used only by the coast stations duly authorized by their government.

923 (4) In cases of distress, the use of the alarm signal is governed by 876; in the case of an urgent cyclone warning, the transmission of the warning must not begin until two minutes after the end of the alarm signal.

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934 SEC. 35. (1) In radiotelegraphy, the urgency signal consists of three repetitions of the group XXX, sent with the letters of each group and the successive groups clearly separated from each other. It is sent before the call.

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943 SEC. 40. (1) In radiotelegraphy, the safety signal consists of three repetitions of the group TTT, sent with the letters of each group and the successive groups clearly separated from each other. It is sent before the call.

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940 SEC. 38. (1) Mobile stations which hear the urgency signal must continue to listen for at least three minutes. At the end of this period, if no urgency message has been heard, they may resume their normal service.

941 (2) However, land and mobile stations which are in communication on frequencies other than those used for the transmission of the urgency signal and of

the call which follows it may continue their normal work without interruption provided the urgency message is not addressed "to all stations" (CQ).

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947 SEC. 42. (1) With the exception of messages transmitted at fixed times, the safety signal, when it is used in the maritime mobile service, must be transmitted towards the end of the first available period of silence (see 733); the message is transmitted immediately after the period of silence.

948 (2) In the cases prescribed in 1050, 1053 and 1056, the safety signal and the message which follows it must be transmitted as soon as possible, but must be repeated as just indicated, at the end of the first period of silence which follows.

949 SEC. 43. All stations hearing the safety signal must continue to listen on the frequency on which the safety signal has been transmitted until they are satisfied that the message is of no interest to them. They must, moreover, not make any transmissions likely to interfere with the message.

Article 38

950 The order of priority of communications in the mobile service is as follows:

1. Distress calls, distress messages and distress traffic.
2. Communications preceded by the urgency signal.
3. Communications preceded by the safety signal.
4. Communications relative to radio direction-finding bearings.
5. Radiotelegrams relative to the navigation and safe movement of aircraft.
6. Radiotelegrams relative to the navigation, movements, and needs of ships; weather observation messages destined for an official meteorological service.
7. Government radiotelegrams for which priority right has been claimed.
8. Service radiotelegrams relating to the working of the radiocommunication service or to radiotelegrams previously transmitted.
9. All other communications.

EXTRACTS FROM TELEGRAPH REGULATIONS (PARIS REVISION, 1949)

Article 34

249 SEC. 4. Morse Code Signals.

Spacing and length of the signals:

250 (a) A dash is equal to three dots;

251 (b) The space between the signals forming the same letter is equal to one dot;

252 (c) The space between two letters is equal to three dots;

253 (d) The space between two words is equal to seven dots;

254 (e) On the Wheatstone instrument, where perforators are used, the space between two letters shall be equal to one "center hole" and the space between two words shall be equal to three "center holes."

APPENDIX II

Extracts from the Rules and Regulations of the Federal Communications Commission

This appendix contains reproductions of selected portions of the Rules and Regulations of the Federal Communications Commission. These reproductions reflect amendments to the Rules and Regulations through the following dates: Part 1—March 1, 1974; Part 2—May 1, 1974; Part 13—March 1, 1974; Part 17—March 1, 1974; Part 81—March 28, 1974; Part 83—March 7, 1974.

PART 1—RULES RELATING TO PRACTICE AND PROCEDURE

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§ 1.89 Notice of violations.

(a) Except in cases of willfulness or those in which public health, interest, or safety requires otherwise, any licensee who appears to have violated any provision of the Communications Act or any provision of this chapter will, before revocation, suspension, or cease and desist proceedings are instituted, be served with a written notice calling these facts to his attention and requesting a statement concerning the matter. FCC Form 793 may be used for this purpose.

(b) Within 10 days from receipt of notice or such other period as may be specified, the licensee shall send a written answer, in duplicate, direct to the office of the Commission originating the official notice. If an answer cannot be sent nor an acknowledgment made within such 10-day period by reason of illness or other unavoidable circumstances, acknowledgment and answer shall be made at the earliest practicable date with a satisfactory explanation of the delay.

(c) The answer to each notice shall be complete in itself and shall not be abbreviated by reference to other communications or answers to other notices. In every instance the answer shall contain a statement of action taken to correct the condition or omission complained of and to preclude its recurrence. In addition:

(1) If the notice relates to violations that may be due to the physical or electrical characteristics of transmitting apparatus and any new apparatus is to be installed, the answer shall state the date such apparatus was ordered, the name of the manufacturer, and the promised date of delivery. If the installation of such apparatus requires a construction permit, the file number of the application shall be given, or if a file number has not been assigned by the Commission, such identification shall be given as will permit ready identification of the application.

(2) If the notice of violation relates to lack of attention to or improper operation of the transmitter, the name and license number of the operator in charge shall be given.

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PART 2—FREQUENCY ALLOCATIONS AND TREATY MATTERS; GENERAL RULES AND REGULATIONS

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§2.1 Definitions.

The following definitions are issued:

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Base station. A land station in the land mobile service carrying on a service with land mobile stations.

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Carrier. In a frequency stabilized system, the sinusoidal component of a modulated wave whose frequency is independent of the modulating wave; or the output of a transmitter when the modulating wave is made zero; or a wave generated at a point in the transmitting system and subsequently modulated by the signal; or a wave generated locally at the receiving terminal which, when combined with the side bands in a suitable detector, produces the modulating wave.

Carrier frequency. The frequency of the carrier.

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Citizens radio service. A radiocommunciation service of fixed, land, and mobile stations intended for personal or business radiocommunications, radio signaling, control of remote objects or devices by means of radio, and other purposes not specifically prohibited.

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Domestic fixed public service. A fixed service, the stations of which are open to public correspondence, for radiocommunications originating and terminating solely at points within: (a) the State of Alaska, or (b) the State of Hawaii, or (c) the contiguous 48 states and the District of Columbia, or (d) a single possession of the United States. Generally, in cases where service is afforded on frequencies above 72 MHz, radiocommunications between the contiguous 48 States (including the District of Columbia) and Canada or Mexico, or radiocommunications between the State of Alaska and Canada, are deemed to be in the domestic fixed public service.

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Experimental station. A non-amateur station utilizing radio waves in experiments with a view to the development of science or technique.

Facsimile. A system of telecommunication for the transmission of fixed images, with or without halftones, with a view to their reproduction in a permanent form.

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Fixed service. A service of radiocommunication between specified fixed points.

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Industrial radio services. Any service of radiocommunication essential to, operated by, and for the sole use of, those enterprises which for purposes of safety or other necessity require radiocommunication in order to function efficiently, The radio transmitting facilities of the industrial radio services are defined as fixed, land, mobile or radiolocation stations.

Industrial, scientific and medical equipment (ISM equipment). Devices which use radio waves for industrial, scientific, medical, or any other purposes including the transfer of energy by radio and which are neither used nor intended to be used for radiocommunication.

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Land station. A station in the mobile service not intended to be used while in motion.

Land transportation radio service. Any private service of radiocommunication essential to the conduct of certain land transportation activities and operated for the use of persons engaged in those activities, the transmitting facilities of which are defined as fixed, land, mobile or radiolocation stations.

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Mobile station. A station in the mobile service intended to be used while in motion or during halts at unspecified points.

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Primary standard of frequency. The primary standard of frequency for radio frequency measurements shall be the standard of frequency maintained by the National Bureau of Standards, Department of Commerce, Boulder, Colorado. The operating frequency of all radio stations will be determined by comparison with this standard or through the standard signals of stations WWV, WWVH, or WWVB of the National Bureau of Standards.

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Public correspondence. Any telecommunication which the offices and stations must, by reason of their being at the disposal of the public, accept for transmission.

Public safety radio service. Any service of radiocommunication essential either to the discharge of non-Federal governmental functions or the alleviation of an emergency endangering life or property, the radio transmitting facilities of which are defined as fixed, land, mobile, or radiolocation stations.

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§ 2.101 Nomenclature of frequencies.

Band No.	Frequency subdivision	Frequency range
4	VLF (very low frequency)	Below 30 kHz
5	LF (low frequency)	30 to 300 kHz
6	MF (medium frequency)	300 to 3000 kHz
7	HF (high frequency)	3 to 30 MHz
8	VHF (very high frequency)	30 to 300 MHz
9	UHF (ultra high frequency)	300 to 3000 MHz
10	SHF (super high frequency)	3 to 30 GHz
11	EHF (extremely high frequency)	30 to 300 GHz

§ 2.102 Assignment of frequencies.

(a) Except as otherwise provided in this section, the assignment of frequencies and bands of frequencies to all stations and classes of stations and the licensing and authorizing of the use of all such frequencies between

10 kHz and 90 GHz, and the actual use of such frequencies for radiocommunication or for any other purpose, including the transfer of energy by radio, shall be in accordance with the Table of Frequency Allocations in § 2.106.

(b) On the condition that harmful interference will not be caused to services operating in accordance with the Table of Frequency Allocations the following exceptions to paragraph (a) of this section may be authorized:

(1) In individual cases the Commission may, without rule-making proceedings, authorize on a temporary basis only, the use of frequencies not in accordance with the Table of Frequency Allocations for projects of short duration or emergencies where the Commission finds that important or exceptional circumstances require such utilization. Such authorizations are not intended to develop a service to be operated on frequencies other than those allocated such service.

(2) A station for the development of techniques or equipment to be employed by services or classes of stations set forth in columns 8 and 9 of the Table of Frequency Allocations may be authorized the use of frequencies allocated to those services or classes of stations.

(3) Experimental stations engaged solely in scientific or technical radio experiments not related to an existing or proposed service nor intended to develop a proposed service or specific use of radio may be authorized the use of any frequency which is in a band allocated to the fixed, land mobile or broadcasting services or to one of these services shared with another service.

(4) Experimental stations engaged in communications essential to research projects when existing communication facilities are inadequate may be authorized the use of any frequency which is in a band allocated to the fixed, land mobile, or broadcasting services or to one of those services shared with another service.

(5) Experimental stations engaged solely in ionospheric sounding by means of the technique of sweeping a band of frequencies may be authorized the use of any band or bands of frequencies not allocated, on an exclusive or shared basis, to the radio astronomy service.

(6) Experimental stations to be operated pursuant to a contractual agreement with the United States Government and intended for the sole and express purpose of developing equipment or a technique to be employed by stations belonging to and operated by the United States may be authorized the use of any frequency which is not in a band allocated, on an exclusive or shared basis, to the radio astronomy service.

(7) Experimental stations intended for the sole and express purpose of developing equipment or a technique to be employed by stations under the jurisdiction of a foreign government may be authorized the use of any frequency which is not in a band allocated to the amateur service or the radio astronomy service.

(8) In the event a band is reallocated so as to delete its availability for use by a particular service, the commission may provide for the further interim use of the band by stations in that service for a temporary, specific period of time.

(9) Assignments made pursuant to the Land Mobile Spectrum Management program in the Chicago Region.

(c) The use of frequencies in the bands above 25 MHz allocated exclusively to Government stations and the use of frequencies below 25 MHz which may not be in accordance with § 2.106 may be authorized to non-Government stations in those instances where the Commission finds, after consultations with the appropriate Government agency or agencies, that such assignment is necessary for intercommunication with Government stations or where such use by non-Government stations is required for coordination with Government activities.

(d) Aircraft stations may communicate with stations of the maritime mobile service. They shall then conform to those provisions of the Radio Regulations which relate to the maritime mobile service. For this purpose aircraft stations should use the frequencies allocated to the maritime mobile service. However, having regard to interference which may be caused by aircraft stations at high altitudes, maritime mobile frequencies in the bands above 30 MHz shall not be used by aircraft stations in any specific area without the prior agreement of all administrations of the area in which interference is likely to be caused. In particular, aircraft stations operating in Region 1 should not use frequencies in the bands above 30 MHz allocated to the maritime mobile service by virtue of any agreement between administrations in that Region.

(e) Non-Government services operating on frequencies in the band 25–50 MHz must recognize that it is shared with various services of other countries; that harmful interference may be caused by skywave signals received from distant stations of all services of the United States and other countries radiating power on frequencies in this band; and that no protection from such harmful interference generally can be expected. Persons desiring to avoid such harmful interference should consider operation on available frequencies higher in the radio spectrum not generally subject to this type of difficulty.

(f) The stations of a service shall use frequencies so separated from the limits of a band allocated to that service as not to cause harmful interference to the service to which the frequency bands immediately adjoining are allocated.

(g) In the bands above 25 MHz which are allocated to the non-Government land mobile service, fixed stations may be authorized on the following conditions:

(1) That such stations are authorized in the service shown in Column 11 of the Table of Frequency Allocations in the band in question;

(2) That harmful interference will not be caused to services operating in accordance with the Table of Frequency Allocations.

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§ 2.201 Emission, modulation, and transmission characteristics.

The following system of designating emission, modulation and transmission characteristics shall be employed.

(a) Emissions are designated according to their classification and their necessary bandwidth.

(b) Emissions are classified and symbolized according to the following characteristics.

(1) Type of modulation of main carrier.

(2) Type of transmission.

(3) Supplementary characteristics.

(c) Types of modulation of main carrier:

	Symbol
(1) Amplitude	A
(2) Frequency (or Phase)	F
(3) Pulse	P

(d) Types of transmission:

	Symbol
(1) Absence of any modulation intended to carry information	0
(2) Telegraphy without the use of a modulating audio frequency	1
(3) Telegraphy by the on-off keying of a modulating audio frequency or audio frequencies, or by the on-off keying of the modulated emission (special case: an unkeyed modulated emission)	2
(4) Telephony (including sound broadcasting)	3
(5) Facsimile (with modulation of main carrier either directly or by a frequency modulated sub-carrier)	4
(6) Television (visual only)	5
(7) Four-frequency diplex telegraphy	6
(8) Multichannel voice-frequency telegraphy	7
(9) Cases not covered by the above	9

(e) Supplementary characteristics:

(1) Double sideband	(None)
(2) Single sideband:	
(i) Reduced carrier	A
(ii) Full carrier	H
(iii) Suppressed carrier	J
(3) Two independent sidebands	B
(4) Vestigial sideband	C
(5) Pulse:	
(i) Amplitude modulated	D
(ii) Width (or duration) modulated	E
(iii) Phase (or position) modulated	F
(iv) Code modulated	G

(f) The classification of typical emissions is tabulated as follows:

Type of modulation of main carrier	Type of transmission	Supplementary characteristics	Symbol
Amplitude modulation	With no modulation		A0
	Telegraphy without the use of a modulating audio frequency (by on-off keying).		A1
	Telegraphy by the on-off keying of an amplitude modulating audio frequency or audio frequencies, or by the on-off keying of the modulated emission (special case: an unkeyed emission amplitude modulated).		A2
	Telephony	Double sideband	A3
		Single sideband, reduced carrier	A3A
		Single sideband, suppressed carrier	A3J
		Two independent sidebands	A3B
	Facsimile (with modulation of main carrier either directly or by a frequency modulated subcarrier).		A4
	Facsimile	Single sideband, reduced carrier	A4A
	Television	Vestigial sideband	A5C
	Multichannel voice-frequency telegraphy	Single sideband, reduced carrier	A7A
	Cases not covered by the above, e.g., a combination of telephony and telegraphy.	Two independent sidebands	A9B
Frequency (or Phase) modulation	Telegraphy by frequency shift keying without the use of a modulating audio frequency: one of two frequencies being emitted at any instant.		F1
	Telegraphy by the on-off keying of a frequency modulating audio frequency or by the on-off keying of a frequency modulated emission (special case: an unkeyed emission, frequency modulated).		F2
	Telephony		F3
	Facsimile by direct frequency modulation of the carrier.		F4
	Television		F5
	Four-frequency diplex telegraphy		F6
	Cases not covered by the above, in which the main carrier is frequency modulated.		F9
Pulse modulation	A pulsed carrier without any modulation intended to carry information (e.g. radar).		P0
	Telegraphy by the on-off keying of a pulsed carrier without the use of a modulating audio frequency.		P1D
	Telegraphy by the on-off keying of a modulating audio frequency or audio frequencies, or by the on-off keying of a modulated pulsed carrier (special case: an unkeyed modulated pulsed carrier).	Audio frequency or audio frequencies modulating the amplitude of the pulses.	P2D
		Audio frequency or audio frequencies modulating the width (or duration) of the pulses.	P2E
		Audio frequency or audio frequencies modulating the phase (or position) of the pulses.	P2F
	Telephony	Amplitude modulated pulses	P3D
		Width (or duration) modulated pulses	P3E
		Phase (or position) modulated pulses	P3F
		Code modulated pulses (after sampling and quantization).	P3G
	Cases not covered by the above in which the main carrier is pulse modulated.		P9

(g) Type B emission: As an exception to the above principles, damped waves are symbolized in the Commission's rules and regulations as type B emission.

(h) Whenever the full designation of an emission is necessary, the symbol for that emission, as given above, shall be preceded by a number indicating in kilohertz the necessary bandwidth of the emission. Bandwidths shall generally be expressed to a maximum of three significant figures, the third figure being almost always a nought or a five.

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PART 81—STATIONS ON LAND IN THE MARITIME SERVICES

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§ 81.7 Operational.

(a) *Safety communication.* The transmission or reception of distress, alarm, urgency, or safety signals, or any communication preceded by one of these signals, or any form of radiocommunication which, if delayed in transmission or reception, may adversely affect the safety of life or property.

(b) *Superfluous radiocommunication.* Any transmission that is not necessary in properly carrying on the service for which the station is licensed.

(c) *Harmful interference.* Any emission, radiation, or induction which endangers the functioning of a radionavigation service or of other safety services, or seriously degrades, obstructs, or repeatedly inter-

rupts a radiocommunication service operating in accordance with regulations in this chapter.

(d) *Distress signal.* (1) The distress signal is the international radiotelegraph or radiotelephone signal which indicates that a ship, aircraft, or other vehicle is threatened by grave and imminent danger and requests immediate assistance.

(2) In radiotelegraphy, the international distress signal consists of the group "three dots, three dashes, three dots", transmitted as a single signal in which the dashes are emphasized so as to be distinguished clearly from the dots.

(3) In radiotelephony, the international distress signal consists of the oral enunciation of the word "May day", pronounced as the French expression "m'aider". In case of distress, transmission of this particular signal is intended to insure recognition of a radiotelephone distress call by stations of any nationality.

(e) [Reserved]

(f) *Urgency signal.* (1) The urgency signal is the international radiotelegraph or radiotelephone signal which indicates that the calling station has a very urgent message to transmit concerning the safety of a ship, aircraft, or other vehicle, or of some person on board or within sight.

(2) In radiotelegraphy, the international urgency signal consists of three repetitions of the group "XXX", sent before the call, with the letters of each group and the successive groups clearly separated from each other.

(3) In radiotelephony, the international urgency signal consists of three oral repetitions of the word "Pan" pronounced as the French word "panne" and sent before the call.

(g) *Safety signal.* (1) The safety signal is the international radiotelegraph or radiotelephone signal which indicates that the station sending this signal is ready to transmit a message concerning the safety of navigation or giving important meteorological warnings.

(2) In radiotelegraphy, the international safety signal consists of three repetitions of the group "TTT", sent before the call, with the letters of each group and the successive groups clearly separated from each other.

(3) In radiotelephony, the international safety signal consists of three oral repetitions of the French word "Securite", sent before the call.

(h) *Distress traffic.* All messages relative to the immediate assistance required by the ship, aircraft, or other vehicle in distress.

(i) *500 kilohertz silent period.* The three-minute period twice an hour beginning at x h 15 and x h 45, Greenwich mean time (GMT), during which the International Radio Regulations require that all transmissions (except for certain emissions designated in those Regulations) must cease on all frequencies within a designated frequency-band centered on 500 kHz.

(j) *Watch.* The act of listening on a designated frequency.

(k) *Calling.* Transmission from a station solely to secure the attention of another station, or other stations, for a particular purpose.

(l) *Working.* Radiocommunication carried on, for a purpose other than calling, by any station or stations using telegraphy, telephony, or facsimile.

(m) *Control point.* An operating position associated with a particular station or stations which is:

(1) Under the control and supervision of the station licensee or his authorized agent; and

(2) A place at which the required monitoring and control facilities are available; and

(3) A place at which a duly licensed operator (or other person if the requirement for a licensed operator is waived by the Commission) responsible for the operation of the transmitter(s) is stationed.

(n) *Dispatch point.* A place from which radiocommunication may be transmitted under supervision of a responsible operator at a control point.

(o) *Port operations.* Communications in or near a port, or in locks or waterways, between coast stations and ship stations, or between ship stations, in which messages are restricted to those relating to the operational handling, the movement and the safety of ships and, in emergency, to the safety of persons. Messages which are of a public correspondence nature shall be excluded.

(p) *Navigational.* Safety communications in the maritime mobile service pertaining to the maneuvering of vessels or the directing of vessel movements. Such communications are primarily for the exchange of information between ship stations and secondarily between ship stations and coast stations.

(q) *Environmental.* Communications in the maritime mobile service for the broadcast of information pertaining to the environmental conditions in which vessels operate, i.e., weather, sea conditions, time signals of a grade adequate for practical navigation, notices to mariners, and hazards to navigation

(r) *State control.* Communications, other than Port Operations, in the maritime mobile service on very high frequencies (VHF) between coast stations, operated by a government, other than Federal, boating administration and ship stations in which messages are restricted to those of immediate concern and are related directly to the regulation and control, or rendering of assistance.

(s) *Commercial.* Radiocommunication, other than Port Operations, on very high frequencies (VHF) between coast stations and ship stations aboard commercial transport vessels, or between ship stations aboard commercial transport vessels, in which messages are limited to those pertaining to commercial, operational, or economic matters related directly to the purposes for which the ship is used, including the piloting of vessels, movements of vessels, and to meet immediate needs, for obtaining vessel supplies and scheduling of repairs, or modification of vessels of immediate need.

(t) *Noncommercial.* Radiocommunication, other than Port Operations, on very high frequencies (VHF) between coast stations and ship stations aboard vessels other than commercial transport vessels, or between ship stations aboard vessels other than commercial transport vessels, in which messages are limited to those pertaining to the needs of the vessel, for example, during rendezvous, maneuvers, during cruise, piloting of vessels, movements of vessels, obtaining of vessel supplies to meet immediate needs, scheduling of repairs, berthing, and accommodations.

(u) *Mississippi River System.* The system of frequencies and facilities provided by public coast and ship stations for radiocommunication on the Mississippi River and connecting inland waters other than the Great Lakes.

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§ 81.64 Equipment and service tests.

(a) Equipment and service tests of any radio transmitting facilities authorized by a construction permit

issued by the Commission in respect to a station subject to this part may be conducted as prescribed in paragraphs (b), (c), and (d) of this section: *Provided*, That necessary precautions are taken to avoid interference to the service of other authorized stations.

(b) Equipment test: Upon completion of construction or installation of radio transmitting facilities in a station in exact accordance with the terms of the related construction permit, the technical provisions of the application therefor, and the rules and regulations governing the class of station concerned, and prior to the filing of an application for license or modification of license, the permittee is authorized to test the equipment in accordance with applicable terms of the construction permit for a period not to exceed 10 days: *Provided*, That the Commission's Engineer in Charge of the radio district in which the station is located is notified two days in advance of the beginning of tests and that the permittee is not notified by the Commission to cancel, suspend, or change the date(s) for such tests.

(c) Service test: When equipment tests have been completed, and after application for station license or modification thereof has been filed with the Commission showing the transmitting equipment and associated apparatus to be in satisfactory operating condition, the permittee is authorized to conduct service tests in exact accordance with the terms of the construction permit for a period not to exceed 30 days: *Provided*, That the Commission's Engineer in Charge of the radio district in which the station is located is notified two days in advance of the beginning of such tests and that the permittee is not notified by the Commission to cancel, suspend, or change the date(s) for such tests.

(d) Limitations: The authorization for tests embodied in paragraphs (b) and (c) of this section shall not be construed as constituting a license to operate but as a necessary part of the authorized construction. Equipment and service tests shall not commence after the expiration date of the construction permit.

(e) Common carrier service tests: When new stations in common carrier services are ready in all respects to be placed in service, equipment and service tests are authorized to be conducted as outlined in paragraphs (b) and (c) of this section: *Provided*, All necessary precautions are taken to avoid interference to any other authorized station. No service may be furnished to the public during the equipment test period. Charges for services furnished during the service test period may be made, pursuant to the provisions of legally applicable tariffs.

NOTE: See § 61.62 of this chapter.

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§ 81.179 Message charges.

(a) (1) No charge shall be made for the service of any public coast station unless effective tariffs applicable to such service are on file with the Commission, pursuant to the requirements of Section 203 of the Communications Act and Part 61 of this chapter.

(2) No charge shall be made for the service of any station subject to this part, other than a public coast station, except as provided by and in accordance with § 81.352.

(b) No charge shall be made by any station in the maritime mobile service of the United States for the transmission of distress messages and replies thereto in connection with situations involving the safey of life and property at sea.

(c) No charge shall be made by any station in the maritime mobile service of the United States for the transmission, receipt, or relay of the information concerning dangers to navigation designated in § 83.303 (b) of this chapter, originating on a ship of the United States or of a foreign country.

(d) Any common carrier subject to the Communications Act may furnish reports of positions of ships at sea to newspapers of general circulation, either at a nominal charge or without charge, provided the name of such common carrier is displayed along with such ship position reports.

(e) Any common carrier subject to the Communications Act may render to any agency of the United States Government free service in connection with the preparation for the national defense. Every such carrier rendering any such free service shall make and file, in duplicate, with the Commission, on or before the 31st day of July and on or before the 31st day of January in each year, reports covering the periods of 6 months ending on the 30th day of June and the 31st day of December, respectively, next prior to said dates. These reports shall show the names of the agencies to which free service was rendered pursuant to this paragraph, the general character of the communications handled for each agency, and the charges in dollars which would have accrued to the carrier for such service rendered to each agency if charges for all such communications had been collected at the published tariff rates.

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§ 81.194 Maintenance of station log.

(a) Each station subject to this part which is required, under the provisions of this part pertaining to the particular class of station, to keep a radio station log, shall, in addition, comply with the applicable provisions of the following paragraphs of this section; the station licensee and the licensed radio operator (when a licensed operator is required) in charge of the station shall be responsible for compliance with this section.

(b) The log shall be kept in an orderly manner, in useable form, and in such detail that the information required for the particular class of station concerned is readily available. Key letters or abbreviations may be used if their proper meaning or explanation is contained elsewhere in the same log.

(c) The station log or any portion thereof shall not be erased, obliterated, or wilfully destroyed within the period of retention required by § 81.115. However, during this period any necessary correction may be made of such log but only by the person originating the entry and that person shall strike out the erroneous portion, initial the correction made, and indicate the date of correction.

(d) For each station whose antenna structure is required to be illuminated, appropriate entries shall be made in the station log in conformity with the requirements of Part 17 of this chapter.

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§ 81.302 Points of communication.

(a) Subject to the conditions and limitations imposed by the terms of the particular coast station license or by the applicable provisions of this part with

respect to the use of particular radiochannels, public coast stations using telephony are authorized to communicate:

(1) With any ship station or aircraft station operating in the maritime mobile service for the transmission or reception of safety communication;

(2) With any land station for the purpose of facilitating the transmission or reception of safety communication to or from a ship or aircraft station;

(3) With public ship stations, government ship stations, aeronautical public service stations on board aircraft, and government aircraft stations, for the transmission or reception of public correspondence:

(i) When the mobile station uses telephony on a frequency assignment designated in Part 83 of this chapter for ship-to-shore public correspondence by means of telephony;

(ii) In respect to a United States Government or foreign ship or aircraft station, when such mobile station uses telephony on a frequency assignment available in accordance with the International Radio Regulations for use by ship stations for communication by means of telephony with public coast stations.

(4) With marine fixed stations when the coast station uses for this purpose a frequency assignment below 4000 kHz upon the express condition that neither harmful interference nor intolerable delay is caused to communication with mobile stations.

(b) Upon application, a public coast station using telephony may be specifically authorized by the terms of its station authorization to communicate with a designated station (government or non-government) at a remote fixed location isolated from the mainland where other communication facilities are not available: *Provided,*

(1) The station with which communication is carried on is duly authorized to communicate with the particular coast station involved; and

(2) The station with which communication is carried on shall transmit by telephony to the coast station:

(i) On a frequency assignment available for ship-to-shore public correspondence in accordance with the provisions of Part 83 of this chapter for public ship stations using telephony; or

(ii) On any other frequency assignment designated for this purpose in any other section of the Commission's rules or, with respect to United States Government stations, on any government frequency assignment duly authorized by the Government for this purpose.

(3) Any communication carried on shall be confined exclusively to that absolutely necessary for public safety or the protection of life or property; and

(4) Neither harmful interference nor intolerable delay is caused to safety communication with ship stations.

(c) Upon application, a public coast station using telephony may be authorized to transmit meteorological and marine navigational information, of benefit to mariners, additionally to designated fixed locations, whenever the same information is transmitted by such coast station simultaneously and primarily to ship stations: *Provided,* A sufficient need for such authorization is shown to exist.

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§ 81.305 Frequencies for calling and distress.

(a) In the band 1605–4000 kHz, the frequency 2182 kHz is the international radiotelephone distress and general calling frequency for the maritime mobile service. In the band 156–162 MHz, the frequency 156.800 MHz is the national distress, safety and calling frequency for the maritime mobile service. 2182 kHz and 156.800 MHz may be used by public coast stations solely for transmission of:

(1) Distress signals and traffic as provided in Subpart G of this part.

(2) The international urgency signal, and very urgent messages (preceded by this signal) concerning the safety of a ship, aircraft or other vehicle, or the safety of some person on board or within sight of such ship, aircraft, or vehicle.

(3) The international safety signal and call. The safety message which follows shall, where practicable, be sent on a working frequency and a suitable announcement to this effect shall be made at the end of the call.

(4) Normal calls, replies, and brief radio operating signals but only when the use of a different carrier frequency for this function appears to be impracticable by reason of operating or equipment limitations of a mobile station: *Provided,* That as a general rule radiotelephone stations on board foreign ships shall be called on the frequency 2182 kHz.

(5) Brief announcements specifying the nature of a particular communication to be transmitted soon thereafter on other radio channel(s) by the same coast station to a plurality of mobile stations, when such communication will be of general interest to mobile stations of the maritime mobile service, including ordinary weather and hydrographic information, or will consist of lists of mobile stations with which the coast station desires to communicate.

(6) Brief test signals in accordance with the provisions of § 81.311, as may be necessary to determine whether the radio transmitting equipment of the station is in good working condition on this frequency.

(b) Where the ship station is known to maintain a watch on both 156.800 MHz and a public coast working frequency, calling and replying by a public coast station should be conducted on a frequency authorized primarily for working. Prior to initiating the call, the coast station shall determine that the channel is not in use and that interference will not be caused to any communication in progress.

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§ 81.310 Identification of station.

(a) All radiotelephone emissions of a public coast station shall be clearly identified by voice transmission therefrom in the English language of either the official call sign assigned to that station by the Commission or the approximate geographic location of the station as approved [1] in each case by the Commission upon request made by the station licensee or permittee: *Provided,* That in lieu of identification of the station by voice, the official call sign may be clearly transmitted by tone-modulated telegraphy in the International Morse Code either by a duly licensed radiotelegraph operator or by means of an automatic device approved [2] for this purpose by the Commission.

[1] Such voice identification as "Washington marine operator" to indicate that the station is located at or near Washington, D.C., may be approved if there will be no conflict with identification of any other station.

[2] The conditions to be met by such a device in order to obtain the approval of the Commission will be determined and will be incorporated in proposed rule making.

Identification as herein prescribed shall be made:

(1) Upon completion of each communication with any other station;

(2) At the beginning and upon conclusion of each transmission made for any other purpose.

§ 81.311 Procedure in testing.

(a) Public coast stations using telephony are authorized to carry on such routine tests as may be required for the proper maintenance of the station provided each such station shall use every precaution to insure that, when conducting operational transmitter tests, the emissions of the station will not cause harmful interference. Radiation must be reduced to the lowest practicable value and if feasible shall be entirely suppressed. When radiation is necessary or unavoidable, the testing procedure described below shall be followed:

(1) The licensed radio operator responsible for operation of the transmitting apparatus shall ascertain by careful listening that the test emissions will not be likely to interfere with transmissions in progress;

(2) The official call sign and the geographic location of the testing station, followed by the word "test", shall be announced by voice on the radio-channel being used for the test, as a warning that test emissions are about to be made on that frequency;

(3) If, as a result of the announcement prescribed in subparagraph (2), any station transmits by voice the word "wait", testing shall be suspended. When, after an appropriate interval of time, such announcement is repeated and no response is observed, and careful listening indicates that harmful interference should not be caused, the operator shall proceed as set forth in subparagraph (4) of this paragraph;

(4) The operator shall announce the word "testing" followed in the case of a voice transmission test by the count "1, 2, 3, 4 • • • etc." or by test phrases or sentences not in conflict with normal operating signals; or followed, in the case of other emission, by appropriate test signals not in conflict with normal operating signals. At the conclusion of the test, there shall be voice announcement of the official call sign of the testing station and its approximate geographic location.

(b) When testing is conducted on any frequency assignment within the band 2170 kHz to 2194 kHz or within the band 156.75 MHz to 156.85 MHz, the test transmission shall not continue for more than 15 seconds in any 15-minute period.

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§ 81.312 General radiotelephone operating procedure.

(a) *Limitations on calling.* (1) Except when transmitting a general call to all stations within range for announcing or preceding the transmission of distress, urgency, or safety messages, a public coast station shall call the particular station(s) with which it intends to communicate.

(2) Public coast stations shall call ship stations by voice unless it is known that the attention of a particular ship station with which communication is intended may be secured by other means (such as automatic actuation of a selective ringing device).

(3) Public coast stations may use authorized classes of emission for selective calling on each frequency authorized for working. The use of selective calling on either 2182 kHz or 156.8 MHz is prohibited.

(4) Calling a particular station, either by voice or by other means, shall not continue for a period of more than one minute in each instance. If the called station is not heard to reply, that station shall not again be called until after an interval of two minutes. When a station called does not reply to a call sent three times at intervals of two minutes, the calling shall cease and shall not be renewed until after an interval of fifteen minutes; however, if there is no reason to believe that harmful interference will be caused to other communications in progress, the call sent three times at intervals of two minutes may be repeated after a pause of not less than three minutes. In event of an emergency involving safety, the provisions of this subparagraph shall not apply.

(5) Each public coast station, when using selective calling to secure the attention of a ship station with which it intends to communicate, shall transmit the type of signal and the particular signal code necessary to actuate the automatic attention device (selective ringer) known to be installed in the particular ship station and normally used for monitoring the coast station frequency which is used for transmitting such calls.

(6) Except in the event of an emergency involving safety, a public coast station, with respect to operation on any frequency which is used also by other coast stations within the same communication area, shall not answer, or attempt to answer, a ship station until the latter has transmitted the call sign or name of the particular coast station with which it desires to communicate.

(7) A public coast station shall not attempt to communicate with a ship station that has specifically called another coast station until it becomes evident that the called station does not answer, or that communication between the ship station and the called station cannot be carried on because of unsatisfactory operating conditions.

(b) *Time limitation on calling frequency.* Transmission by coast stations on the calling channel of which 2182 kHz or 156.8 MHz is the authorized carrier frequency (including calls, answers, operating signals, and conversation pertaining to safety) shall be kept to a minimum and in general any one exchange of communications shall not exceed three minutes in duration. In the event of distress or other emergency, this time limitation shall not apply.

(c) *Change to working frequency.* After establishing communication with another station by call and reply on the calling channel of which 2182 kHz or 156.8 MHz is the authorized carrier frequency, coast stations shall change to an authorized working channel for the transmission of messages which, under the provisions of this subpart, cannot be transmitted on the respective calling channel.

(d) *Use of busy signal.* A public coast station, when communicating with a ship station which transmits to the coast station on a radio-channel which is a different channel from that used by the coast station for transmission, may transmit a "busy" signal whenever transmission from the ship station is being received and during such other periods of time, pending completion of any one exchange of communications with a particular ship station, as may be considered necessary by the coast station to avoid or minimize interference from other stations.

§ 81.313 Station documents.

(a) Class I public coast stations, and class II public coast stations that provide communication with oceangoing vessels, shall be provided with the following documents:

(1) A valid station license, available in accordance with the provisions of § 81.102;

(2) The necessary operator license(s), available in accordance with the provisions of § 81.159;

(3) The station log required by this part;

(4) Parts 81 and 83 of this chapter;

(5) The Alphabetical List of Call Signs of Stations used in the Maritime Mobile Service;

(6) The List of Ship Stations;

(7) The Manual for use by the Maritime Mobile Service, published by the International Telecommunication Union, Geneva.

NOTE: The Additional Radio Regulations contained in Part B of the Manual do not apply to ships of U.S. registry.

(b) Class II public coast stations that do not provide communication with oceangoing vessels, and class III public coast stations, shall be provided with the documents specified by subparagraphs (1), (2), (3), and (4) of paragraph (a) of this section.

(c) These documents shall be continuously and readily available to the licensed operator on duty during the hours of service of the station.

§ 81.314 Station records.

(a) Public coast stations using telephony shall maintain an accurate radio-telephone log during their hours of service, as hereinafter specified:

(1) Each sheet of the log shall be numbered in sequence and dated and shall include the official call sign of the coast station and also the signature(s) of the licensed operator(s) performing operating duties.

(2) The entry "on duty" shall be made by the operator beginning a duty period, followed by his signature. The entry "off duty" shall be made by the operator being relieved of or terminating a duty period, followed by his signature. All log entries shall be currently completed and all entries shall, unless otherwise stated, be made by a licensed operator on duty. The use of initials or signs is not authorized in lieu of any operator's signature required by this section.

(3) The time of making an entry shall be shown opposite the entry and shall be expressed in Greenwich mean time (GMT), except that, in the Great Lakes region, the time shall be expressed in eastern standard time (e. s. t.) (counted from 0000 to 2400 o'clock, beginning at midnight) and for public coast stations which communicate exclusively with vessels on inland waters of the United States (other than the Great Lakes) the time shall be expressed in local standard time (e.s.t., c.s.t., etc., counted from 0000 to 2400 o'clock, beginning at midnight). The first entry in each hour shall consist of 4 figures; additional entries in the same hour may be expressed in 2 figures by omitting the hour designation. The abbreviation "GMT" (e.s.t. in the Great Lakes area) (e.s.t., c.s.t., etc., for stations serving inland waters exclusively) shall be marked at the head of the column in which the time is entered.

(4) With respect to public coast stations which, by reason of the provisions of Subpart G of this part, are required to maintain a watch on the frequencies 2182 kHz or 156.8 MHz, entries shall be made showing each time this watch is begun, suspended, or concluded; without any requirement, however, of making such entries during interruption of this watch as may be necessary during the hours of service for calling, answering, and exchanging operating signals and safety communications on this frequency. These entries shall be made by the licensed operator(s) on duty who is (are) designated and authorized by the station licensee to do so; the name and signature of the operator(s) making these entries and the operator(s) who actually maintains such watch shall appear in the log and shall be properly related to each particular entry for this purpose.

(5) All radiotelephone distress, urgency or safety signals and communications made or intercepted; the complete text, if possible, of such communications; and any information which may appear to be of importance to safety of life or property shall be entered, together with the time of such observations or occurrence, identification of the radio-channel(s) on which such signals or messages were transmitted or received, and the position of any ship, or other mobile unit in need of assistance, if this can be determined. These entries shall be made by the licensed operator(s) on duty who is (are) designated and authorized by the station licensee to do so; the name and signature of the operator(s) making these entries shall appear in the log and shall be properly related to each particular entry of this category.

(6) All calls transmitted from or received by a coast station shall be entered, showing the call signs or names of vessels; the time, and the assigned frequencies involved: *Provided, however,* That when the manual operations of switching and handling of telephone calls directly between a ship-telephone station and landline telephone facilities are not normally performed by a licensed radio operator, the entries prescribed by this paragraph may be omitted from the station log upon the express condition that equivalent records shall be currently maintained by the station licensee. Such records shall be made available upon request of an authorized Commission representative. The equivalent records shall include the time and such other notations as are necessary to identify the frequency(s) employed and the station(s) communicated with or heard. In addition, for each communication handled, a notation shall be made of the points of origin and destination of the communication. Local standard time may be used to record the occurrence in the equivalent record in lieu of Greenwich mean time or eastern standard time prescribed by subparagraph (3) of this paragraph: *Provided,* That the licensee may be required, upon request of an authorized Commission representative, to convert the standard time recorded to that specified in subparagraph (3) of this paragraph.

(7) Whenever harmful interference is experienced by or reported to the responsible operator, an entry shall be made by such operator to that effect, stating the source of the interference, if known.

(8) All test transmissions shall be entered, together with the time of such transmissions, without regard to whether two-way communication with any other station is established.

(9) A daily entry shall be made regarding comparision of the time indicated by the required clock(s) with standard time, including a statement of any deviations observed and corrections made.

(10) Failure of apparatus to operate as required, failure of power supply, and incidents tending to unduly delay communication shall be entered.

(11) All measurements of the transmitter frequency(s) shall be entered, including such deviations from the authorized carrier frequency(s) as may be observed, and a statement of any corrective action taken.

(12) An entry shall be made giving pertinent details of all installation, service, or maintenance work performed which may affect the proper operation of the station. The entry shall be made, signed, and dated

by the responsible licensed operator who supervised or performed the work, and unless he is regularly employed on a full-time basis at the station and has his operator licensed properly posted, shall also include his mail address and the class, serial number, and expiration date of his license.

(13) Entries shall be made also in reference to operation of the antenna tower lights when such entries are required by reason of applicable provisions of Subpart G of this part.

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PART 83—STATIONS ON SHIPBOARD IN THE MARITIME SERVICES

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§ 83.6 Operational.

(a) *Safety communication.* The transmission or reception of distress, alarm, urgency, or safety signals, or any communication preceded by one of these signals, or any form of radiocommunication which, if delayed in transmission or reception, may adversely affect the safety of life or property.

(b) *Superfluous radiocommunication.* Any transmission that is not necessary in properly carrying on the service for which the station is licensed.

(c) *Harmful interference.* Any emission, radiation, or induction which endangers the functioning of a radionavigation service or of other safety services, or seriously degrades, obstructs, or repeatedly interrupts a radiocommunication service operating in accordance with regulations in this chapter.

(d) *500 kilohertz silence period.* The three-minute period twice an hour beginning at x h. 15 and x h. 45, Greenwich mean time, during which the International Radio Regulations require that all transmission (except for certain emissions designated in those Regulations) must cease on all frequencies within a designated frequency band centered on 500 kHz.

(e) *Watch.* The act of listening on a designated frequency.

(f) *Calling.* Transmission from a station solely to secure the attention of another station, or other stations, for a particular purpose.

(g) *Working.* Radiocommunication carried on, for a purpose other than calling, by any station or stations using telegraphy, telephony, or facsimile.

(h) [Reserved]

(i) *Navigational.* Safety communications in the Maritime Mobile Service pertaining to the maneuvering of vessels or the directing of vessel movements. Such communications are primarily for the exchange of information between ship stations and secondarily between ship stations and coast stations.

(j) *Environmental.* Communications in the Maritime Mobile Service, for the broadcast of information pertaining to the environmental conditions in which vessels operate, i.e., weather, sea conditions, time signals of a grade adequate for practical navigation, notices to mariners and hazards to navigation.

(k) *State control.* Communications, other than Port Operations, in the Maritime Mobile Service on very high frequencies (VHF) between coast stations, operated by a government, other than Federal, boating administration and ship stations in which messages are restricted to those of immediate concern and are related directly to the regulation and control, or rendering of assistance.

(l) *Commercial.* Radio communication, other than Port Operations, on very high frequencies (VHF) between coast stations and ship stations aboard commercial transport vessels, or between ship stations aboard commercial transport vessels, in which messages are limited to those pertaining to commercial, operational, or economic matters related directly to the purposes for which the ship is used, including the piloting of vessels, movements of vessels and to meet immediate needs for obtaining vessel supplies, and scheduling of repairs, or modification of vessels.

(m) *Noncommercial.* Radio communication, other than Port Operations, on very high frequencies (VHF) between coast stations and ship stations aboard vessels other than commercial transport vessels, or between ship stations aboard vessels other than commercial transport vessels, in which messages are limited to those pertaining to the needs of the vessel, for example, during rendezvous, maneuvers, during cruise, piloting of vessels, movements of vessels, obtaining of vessel supplies to meet immediate needs, scheduling of repairs, berthing and accommodations.

(n) *Mississippi River System.* The system of frequencies and facilities provided by public coast and ship stations for radiocommunication on the Mississippi River and connecting inland waters other than the Great Lakes.

§ 83.7 Technical.

(a) *Assigned frequency.* The frequency coinciding with the center of an authorized bandwidth of emission shall be specified as the assigned frequency. For single sideband radiotelephone emission the assigned frequency shall be 1.4 kHz above the authorized carrier frequency.

(b) *Authorized bandwidth.* The authorized bandwidth is the occupied bandwidth authorized to be used by a station.

(c) *Authorized carrier frequency.* A specific carrier frequency authorized for use by a station, from which the actual or suppressed carrier frequency is permitted to deviate, solely because of frequency instability, by an amount not to exceed the frequency tolerance.

(d) *Carrier power.* The average power supplied to the antenna transmission line by a transmitter during one radio frequency cycle under conditions of no modulation. This definition does not apply to pulse modulated emissions.

(e) *Frequency tolerance.* The extent to which an actual or suppressed carrier frequency is permitted to depart, solely because of frequency instability, from the authorized carrier frequency. The frequency tolerance is expressed in parts in 10^6 or in hertz.

(f) *Mean power.* The power supplied to the antenna transmission line by a transmitter during normal operation, averaged over a time sufficiently long compared with the period of the lowest frequency encountered in the modulation. A time of $\frac{1}{10}$ second during which the mean power is greatest will be selected normally.

(g) *Occupied bandwith.* The frequency bandwidth such that, below its lower and above its upper fre-

quency limits, the mean powers radiated are each equal to 0.5 percent of the total mean power radiated by a given emission.

(h) *Peak envelope power.* The average power supplied to the antenna transmission line by a transmitter during one radio frequency cycle at the highest crest of the modulation envelope, taken under conditions of normal operation.

(i) *Spurious emission.* Emission on a frequency or frequencies which are outside the necessary band, and the level of which may be reduced without affecting the corresponding transmission of information. Spurious emissions include harmonic emissions, parasitic emissions, and intermodulation products, but exclude emissions in the immediate vicinity of the necessary band, which are a result of the modulation process for the transmission of information.

(j) *Antenna power gain.* The ratio of the power required at the input of a half-wave dipole to the power supplied to the input of the given antenna to produce, in a given direction, the same field at the same distance. When not specified otherwise, the figure expressing the gain of an antenna refers to the gain in the direction of the radiation main lobe.

(k) *Effective radiated power (ERP).* The product of the antenna input power and the antenna power gain. This product should be expressed in watts and is referred to a half-wave dipole. (If specified in a particular direction, effective radiated power is based on the antenna power gain in that direction only.)

(l) *Peak effective radiated power.* For emergency position indicating radiobeacon stations, the average power supplied to the antenna by the transmitter during one radio frequency cycle at the highest crest of the modulation envelope, multiplied by the relative gain of the antenna in a given direction. The relative gain is referenced to a quarter-wave loss free monopole mounted on a one wavelength diameter ground plane.

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§ 83.105 Required channels for radiotelegraphy.

(a) Each ship station using telegraphy on frequencies within the band 405–535 kHz shall be capable of:

(1) Transmitting class A2 or A2H emission and receiving classes A2 and A2H emissions with a carrier frequency of 500 kHz.

(2) Transmitting, in addition, class A1 and either A2 or A2H emissions on at least two working frequencies.

(3) Receiving, in addition, classes A1, A2, and A2H emissions on all other frequencies necessary for their service.

(4) When a radiotelegraph installation is compulsorily fitted for safety purposes, a fourth frequency within this band which is authorized specifically for direction finding must be provided also.

(b) Each ship station using telegraphy on frequencies within the band 90–160 kHz shall be capable of transmitting and receiving class A1 emission on the frequency 143 kHz, and on at least two additional frequencies within this band (except within the band 140–146 kHz) which are authorized for working.

(c) Each ship station using telegraphy on the specific frequencies in the bands between 4000 and 27,500 kHz authorized by the International Radio Regulations, Geneva, 1959, exclusively for the maritime mobile service shall, in each of the bands for which facilities are provided to carry on its service, be capable of transmitting and receiving class A1 emission on at least one frequency authorized for calling and at least two frequencies authorized for working.

(d) Each ship station using, when in Region 2, telegraphy on frequencies within the band 2065–2107 kHz shall be capable of transmitting and receiving class A1 emission on at least one frequency in this band authorized for working in addition to a frequency in this band authorized for calling.

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§ 83.112 General requirements for receiving apparatus.

The radio equipment of each ship station, or marine-utility station, using telegraphy or telephony, must be capable of permitting the reception of the class or classes of emission on the frequency or frequencies, normally received for the service carried on. The technical arrangement of the station apparatus shall be such that the necessary reception of emissions, including in particular that necessary for compliance with the provisions of §§ 83.181 and 83.243 can be readily effected prior to the transmission of any signals or communications by the ship station on the associated transmitting frequency.

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§ 83.114 Clock required.

(a) Except as provided in §§ 83.468 and 83.497, each ship station which is licensed to operate on frequencies below 515 kHz, shall be provided with a reliable clock equipped with a second hand, preferably a sweep second hand. This clock shall be securely mounted in such a position that the entire dial can be easily and accurately observed by the operator from his normal operating position, from the operating position at which he would ordinarily transmit the international radiotelegraph alarm signal by hand, and from the position used for testing the radio telegraph auto alarm (if installed) for response to signals from the testing device.

(b) Except as provided in §§ 83.468 and 83.497, each ship station which is licensed to operate on frequencies above 1500 kHz, shall have available to the operator a reliable clock or timepiece, preferably equipped with a second hand.

§ 83.115 Retention of radio station logs.

(a) All station logs which are required under those provisions of this part pertaining to the particular classes of stations subject to this part shall be retained by the licensee for a period of one year from date of entry and for such additional periods as required by the following subparagraphs:

(1) Station logs involving communications incident to a distress or disaster shall be retained by the station licensee for a period of 3 years from date of entry;

(2) Station logs which include entries of communications incident to or involved in an investigation by the Commission and concerning which the station licensee has been notified shall be retained by the station licensee until such licensee is specifically authorized in writing by the Commission to destroy them;

(3) Station logs incident to or involved in any claim or complaint of which the station licensee has notice shall be retained by such licensee until such claim or complaint has been fully satisfied or until the same has been barred by statute limiting the time for the filing of suits upon such claims.

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(b) Station logs shall be made available to an authorized representative of the Commission upon request.

(c) Ship station logs shall be fully completed at the end of each voyage and before the operator(s) (or other person(s) responsible under the applicable provisions of this part) leave the ship. Unless otherwise authorized by the applicable provisions of this part, the radio log currently in use shall be kept by the licensed operator(s) of the station and during use shall be located at the principal radio operating room of the vessel. At the conclusion of each ocean voyage terminating at a port of the United States (includes Puerto Rico, and Virgin Islands), the original radio log (or a duplicate thereof) dating from the last departure of the vessel from a U.S. port shall be retained under proper custody on board the vessel for a sufficient period of time (not more than 24 hours) to be available for inspection by duly authorized representatives of the Commission. After retention on board the vessel as herein stipulated, the original log (and the duplicate log if provided) may be filed at an established shore office of the station licensee, and shall be retained as stipulated by paragraph (a) of this section.

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(d) Logs of ships of the United States containing entries required to be made by reason of the Great Lakes Agreement or § 83.368(c) of this part shall be kept at the principal radiotelephone operating location while the vessel is being navigated. All entries in their original form required by said agreement or § 83.368(c) shall be retained on board the vessel for a period of not less than one month from the date of entry. After retention on board the vessel as herein stipulated, the entries shall be filed at a place where they will be readily available to an authorized representative of the Commission upon request, and shall be retained as stipulated by paragraph (a) of this section.

(e) The log of the bridge-to-bridge station shall be retained at the principal operating position of the bridge-to-bridge station on board the vessel for a period of not less than 1 month from the date of entry. After the 30-day period, the log may be removed from the bridge-to-bridge station and be filed at a place where it will be readily available to an authorized representative of the Commission upon request, and shall be retained as stipulated by paragraph (a) of this section.

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§ 83.138 Special requirements for ship radar transmitters.

(a) Each radar transmitter authorized in a ship-radar station (other than in a developmental station) must be type-approved by the Commission, pursuant to the type approval procedure set forth in Part 2 of this chapter. In addition to meeting all other applicable requirements such transmitters shall comply with the following limitations and conditions:

(1) The design and construction of the radar transmitter shall be such that, when properly installed, its use will not produce harmful interference to any other radiodetermination service or any maritime mobile service;

(2) The radar transmitter shall not have means available for any external adjustment which can result in a deviation from the terms of the station authorization or any deviation from the applicable technical requirements for ship-radar stations stipulated in this part.

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§ 83.141 Special requirements for survival craft stations.

(a) Equipment provided for use in survival craft stations shall, if capable of transmitting on:

(1) The frequency 500 kHz, be able to use class A2 emission;

(2) The frequency 2182 kHz, be able to use class A3 or A3H emission.

(3) The frequency 8364 kHz, be able to use class A2 emission;

(4) The frequency 121.5 MHz, be able to use A2 or A3 emission and where A3 emission is used the equipment must also be capable of transmitting on 123.1 MHz using A3 emission.

(b) Receivers used in survival craft stations shall be capable of receiving the frequency and types of emission which the transmitter is capable of using: *provided*, That where the transmitter frequency is 8364 kHz the receiver shall be capable of receiving A1 and A2 emission throughout the band 8320–8745 kHz.

(c) Survival craft transmitters operating on the frequency 500 kHz or on the frequency 8364 kHz shall be capable of manual keying. If provisions are made for automatically transmitting the radiotelegraph alarm signal or the radiotelegraph distress signal, such provisions shall meet the requirements of § 83.557 (b)(4)(i), (ii), (v), and (vi).

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Operator Requirements

§ 83.151 Graded values of commercial radio operator authorizations.

(a) The classes of commercial radio operator authorizations are arranged in order of descending value for the purposes of this part, as follows:

T–1, Radiotelegraph first-class operator license.
T–2, Radiotelegraph second-class operator license.
TLT, Temporary limited radiotelegraph second-class operator license.
P–1, Radiotelephone first-class operator license.
P–2, Radiotelephone second-class operator license.
T–3, Radiotelegraph third-class operator permit.
P–3, Radiotelephone third-class operator permit.
RP, Restricted radiotelephone operator permit.

§ 83.152 Operator required.

(a) Except as otherwise provided in § 83.164, the actual operation of transmitting apparatus in any radio station in the maritime mobile or maritime radiodetermination service on board a ship of the United States shall be performed only by a person holding a commercial radio operator license or permit of the required class. The minimum class of radio operator authorization required for operation of each specific classification of station is set forth in this subpart; subject, however, to the provisions of §§ 83.160, 83.161, and 83.162.

(b) As used in this subpart, "radio officer" on a ship of the United States means a person holding at least a first- or second-class radiotelegraph operator license, as prescribed and issued by the Commission.

(c) As used in this subpart, "qualified operator," "operator," or "certified person" on a ship of the United States means a person holding a commercial radio operator license or permit of the proper class, as prescribed and issued by the Commission.

§ 83.153 Location of operator.

When an operator is required for the operation of a station subject to this part, such operator shall, whenever the transmitting apparatus is being operated, be on duty at the principal operating position or a control point of the station and, subject to the lawful authority of the master, shall be in charge of the station.

§ 83.155 Operator(s) required by Title III of Communications Act of 1934.

(a) Each passenger ship of the United States which in accordance with Part II of Title III of the Communications Act is equipped with a radiotelegraph station shall for safety purposes carry at least one radio officer holding a radiotelegraph first-class operator license, and in addition at least one radio officer holding a radiotelegraph first- or second-class operator license or a temporary limited radiotelegraph operator license: *Provided*, That the holder of a radiotelegraph second-class operator license or a temporary limited radiotelegraph operator license may not act as chief radio officer.

(b) Each cargo ship of the United States which in accordance with Part II of Title III of the Communications Act is equipped with a radiotelegraph station, which is not fitted with a radiotelegraph auto alarm in proper operating condition, shall for safety purposes carry at least two radio officers, each of whom shall hold a radiotelegraph first- or second-class operator license or a temporary limited radiotelegraph operator license: *Provided*, That the holder of a radiotelegraph first- or second-class operator license or a temporary limited radiotelegraph operator license may not act as chief radio officer until he has had at least 6 months satisfactory service in the aggregate as a qualified radiotelegraph operator in a station on board a ship or ships of the United States.

(c) Each cargo ship of the United States which in accordance with Part II of Title III of the Communications Act is equipped with a radiotelegraph station, which is fitted with a radiotelegraph auto alarm in proper operating condition, shall for safety purposes carry at least one radio officer holding a radiotelegraph first- or second-class operator license or a temporary limited radiotelegraph operator license, who has had at least 6 months' satisfactory service in the aggregate as a qualified radiotelegraph operator in a station on board a ship or ships of the United States.

(d) Each cargo ship of the United States which in accordance with Part II of Title III of the Communications Act is equipped with a radiotelephone station shall for safety purposes carry at least one qualified operator. Where the power of the station does not exceed 250 watts carrier power or 1,000 watts peak envelope power, such operator shall hold a radiotelephone third-class operator permit or higher class of operator authorization. Where the power of the station exceeds 250 watts carrier power or 1,000 watts peak envelope power, such operator shall, as a minimum, hold a radiotelephone second-class operator license.

(e) Each vessel of the United States transporting more than six passengers for hire, which in accordance with Part III of Title III of the Communications Act is equipped with a radiotelephone installation, shall for safety purposes carry at least one qualified operator. Where the power of the station does not exceed 250 watts carrier power or 1,000 watts peak envelope power, such operator shall hold a radiotelephone third-class operator permit or higher class of operator authorization. Where the power of the station exceeds 250 watts carrier power or 1,000 watts peak envelope power, such operator shall, as a minimum, hold a radiotelephone second-class operator license.

§ 83.156 Operator(s) required by the Safety Convention.

(a) Each ship of the United States which is not subject to Part II of Title III of the Communications Act but which in accordance with the radio provisions of the Safety Convention is equipped with a radiotelegraph station, shall for safety purposes carry at least the number of radio officers specified in subparagraphs (1) and (2) of this paragraph:

(1) If fitted with a radiotelegraph auto alarm in proper operating condition:

(i) Each cargo ship, and each passenger ship carrying or certificated to carry 250 passengers or less, or more than 250 passengers but engaged on a voyage of less than 16 hours duration between two consecutive ports, shall carry at least one radio officer holding a radiotelegraph first- or second-class operator license or a temporary limited radiotelegraph operator license; who has had at least 6 months' satisfactory service in the aggregate as a qualified radiotelegraph operator in a station on board a ship or ships of the United States;

(ii) Each passenger ship carrying or certificated to carry more than 250 passengers and engaged on a voyage exceeding 16 hours duration between two consecutive ports, shall carry at least two radio officers, each of whom shall hold a radiotelegraph first- or second-class operator license or a temporary limited radiotelegraph operator license: *Provided*, That the holder of a radiotelegraph second-class operator license or a temporary limited radiotelegraph operator license may not act as chief radio officer until he has had at least 6 months' satisfactory service in the aggregate as a qualified radiotelegraph operator in a station on board a ship or ships of the United States;

(2) If not fitted with a radiotelegraph auto alarm in proper operating condition:

(i) Each cargo ship shall carry at least two radio officers, each of whom shall hold a radiotelegraph first- or second-class operator license or a temporary limited radiotelegraph operator license: *Provided*, That the holder of a radiotelegraph first- or second-class operator license or a temporary limited radiotelegraph operator license may not act as chief radio officer until he has had at least 6 months' satisfactory service in the aggregate as a qualified radiotelegraph operator in a station on board a ship or ships of the United States;

(ii) Each passenger ship shall carry at least one radio officer holding a radiotelegraph first-class operator license, and in addition at least one radio officer holding a radiotelegraph first- or second-class operator license or a temporary limited radiotelegraph operator license: *Provided*, That the holder of a radiotelegraph second-class operator license or a temporary limited radiotelegraph operator license may not act as chief radio officer.

(b) Each cargo ship of the United States which is not subject to Part II of Title III of the Communications Act but which in accordance with the radio pro-

visions of the Safety Convention is equipped with a radiotelephone station, shall for safety purposes carry at least one qualified operator. Where the power of the station does not exceed 250 watts carrier power or 1,000 watts peak envelope power such operator shall hold a radiotelephone third-class operator permit or higher class of operator authorization. Where the power of the station exceeds 250 watts carrier power or 1,000 watts peak envelope power such operator shall, as a minimum, hold a radiotelephone second-class operator license.

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§ 83.159 Operator requirements for noncompulsory stations.

Description of station	*Minimum operator authorization*
Public ship telegraph, all categories	T–2 or TLT
Limited ship telegraph	T–3
Public or limited ship telephone, more than 250 watts carrier power or 1,000 watts peak envelope power	P–2
Public or limited ship telephone, not more than 250 watts carrier power or 1,000 watts peak envelope power	P–3
Public or limited ship telephone, not more than 100 watts carrier power or 400 watts peak envelope power	RP
Marine utility ship	RP
Ship radiolocation-test, using radar only	P–2, with ship-radar endorsement.

§ 83.160 Limitations applicable to commercial radio operator permits.

(a) With respect to any station subject to this part which the holder of a radiotelegraph or radiotelephone third-class operator permit or restricted radiotelephone operator permit may operate, the following provisions shall apply:

(1) The holder of such a permit is prohibited from making any equipment adjustments that may result in improper transmitter operations;

(2) The operation of the transmitter shall require only the use of simple external switching devices, excluding all manual adjustments of frequency determining elements, and the stability of the frequencies shall be maintained by the transmitter itself within the limits of tolerance specified by § 83.131 or the station license.

§ 83.161 Control by operator.

(a) When the station is a ship station used for telephony, the operator may, if authorized by the station licensee or the master (the latter acting in this respect as the station licensee's agent), permit an unlicensed person to speak into a station microphone: *Provided*, That the operator shall continue to exercise his control so as to ensure operation of the station in compliance with the radio law and the rules and regulations of the Commission.

(b) For the purpose of paragraph (a) of this section, any microphone, without regard to its location on board ship, may be construed to be a station microphone when it is electrically connected to the modulating system of the radiotelephone transmitting apparatus.

(c) When the station is used for telegraphy, transmitted manually by any type of the Morse code, the transmitting telegraph key shall, wherever its location, be manipulated only by a person who holds a radiotelegraph operator license or permit of the proper class.

§ 83.162 Adjustment of transmitting apparatus.

Notwithstanding any other provisions of this subpart (except § 83.164 (a) (2) and (b), which has specific applicability to ship radar stations, and to survival craft stations), all adjustments of radio transmitting apparatus in any station subject to this part during or coincident with the installation, servicing, or maintenance of such apparatus which may affect the proper operation of such station, must be performed by or under the immediate supervision and responsibility of a person holding a first- or second-class operator license or a temporary limited radiotelegraph operator license, who shall be responsible for the proper functioning of the station equipment: *Provided, however*, That only persons holding a radiotelegraph first- or second-class operator license or a temporary limited radiotelegraph operator license, shall perform such functions at radiotelegraph stations transmitting by any type of the Morse code.

§ 83.164 Waivers of operator requirement.

(a) (1) No radio operator license is required for the operation on board ship, during the course of normal rendition of service, of a ship radar station: *Provided*, That the following conditions are met or provided for by the licensee of the station:

(i) The radar equipment shall employ as its frequency determining element a nontunable, pulse type magnetron except that other fixed tuned devices shall be used in the band 14.0 to 14.05 GHz.

(ii) The radar equipment shall be capable of being operated during the course of normal rendition of service in accordance with the radio law and the rules and regulations of the Commission by means of exclusively external controls;

(2) All adjustments or tests during or coincident with the installation, servicing, or maintenance of the equipment must be performed by or under the immediate supervision and responsibility of a person holding a temporary limited radiotelegraph operator license or a first- or second-class commercial radio operator license, radiotelephone or radiotelegraph, containing a ship-radar endorsement, who shall be responsible for the proper functioning of the equipment in accordance with the radio law and the Commission's rules and regulations and for the avoidance and prevention of harmful interference from improper transmitter external effects: *Provided, however*, That nothing in this subparagraph shall be construed to prevent persons not holding such licenses, or not holding such licenses so endorsed, from making replacement of fuses or of receiving-type tubes.

(b) No radio operator authorization is required for the operation of a survival craft station or an emergency position indicating radiobeacon station while it is being used solely for survival purposes or to facilitate search and rescue operations.

(c) No radio operator license is required for the operation of an on-board station: *Provided*, That the limitations set forth in § 83.160(a) (1) and (2) shall apply.

(d) No person is required to be in attendance at the repeater of an on-board station when transmitting during the normal rendition of service.

§ 83.165 Posting of operator authorization.

(a) Except as provided in paragraph (b) of this section, when an operator is required for the operation of a station subject to this part, the original authorization of each such operator while he is em-

ployed or designated as radio operator of the station shall be posted in a conspicuous place at the principal location on board ship at which the station is operated.

(b) An operator who holds a Restricted Radiotelephone Operator Permit or a valid license verification card (FCC Form 758–F) attesting to the existence of a commercial radio operator license of the diploma type, may, in lieu of posting, have such permit or verification card in his personal possession immediately available for inspection upon request by a Commission representative when operating the following:

(1) A station which is not required to be installed on the vessel by reason of statute or treaty to which the United States is a party;

(2) Any class of ship station when the operator is on board solely for the purpose of servicing the radio equipment;

(3) A station of a portable nature.

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General Operating Requirements

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§ 83.177 Order of priority of communications.

(a) The order of priority of radiotelegraph communications in the maritime mobile service on any frequency used for this service shall be as follows:

(1) Distress calls (including the international distress signal for radiotelegraphy), the international radiotelegraph alarm signal, the international radiotelephone alarm signal, distress messages, and distress traffic.

(2) Communications preceded by the international radiotelegraph urgency signal.

(3) Communications preceded by the international radiotelegraph safety signal.

(4) Communications relative to radio direction-finding bearings.

(5) Communications relative to the navigation and safe movement of aircraft.

(6) Communications relative to the navigation, movements, and needs of ships; including weather observation messages destined for an official meteorological service.

(7) Government communications for which priority right has been claimed.

(8) Service communications relating to the working of the radio-communication service or to communications previously transmitted.

(9) All other communications.

(b) The order of priority of radiotelephone communications in the maritime mobile service on any frequency used for this service shall be as follows:

(1) Distress calls (including the international distress signal for radiotelephony),[1] the international radiotelephone alarm signal,[2] distress messages, and distress traffic.

(2) Communications preceded by the international radiotelephone urgency signal, or known to the station licensee or his agent to consist of one or more urgent messages concerning the safety of a ship, aircraft, or other mobile unit or of some person on board or within sight of the ship, aircraft, or mobile unit.

(3) Communications preceded by the international radiotelephone safety signal, or known to the station licensee or his agent to consist of one or more messages concerning the safety of navigation or important meteorological warnings.

(4) Communications known by the station licensee or his agent to consist of one or more messages relative to the navigation, movements, and needs of ships; including weather observation messages destined for an official meteorological service.

(5) Government communications for which priority right has been claimed.

(6) All other communications.

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§ 83.183 Hours of service of ship stations.

(a) Ship stations whose service is not continuous may not close before:

(1) Finishing all operations resulting from a distress call, or urgency or safety signal;

(2) Exchanging, so far as practicable and within the scope of their normal operation, all traffic originating in or destined for public coast stations situated within their range and mobile stations which, being within their range, have indicated their presence before the actual cessation of communication.

§ 83.184 Maintenance of station log.

(a) Each station on board ship subject to this part which is required, under the provisions of this part pertaining to the particular class of station, to keep a radio station log, shall in addition, comply with the applicable provisions of paragraphs (b) and (c) of this section; the station licensee and the licensed radio operator (when a licensed radio operator is required) in charge of the station shall be responsible for compliance with this section.

(b) The log shall be kept in an orderly manner, in useable form, and in such detail that the information required for the particular class of station concerned is readily available. Key letters or abbreviations may be used if their proper meaning or explanation is contained elsewhere in the same log.

(c) The station log or any portion thereof shall not be erased, obliterated, or wilfully destroyed within the period of retention required by § 83.115. However, during this period any necessary correction may be made of such log but only by the person originating the entry and that person shall strike out the erroneous portion, initial the correction made, and indicate the date of correction.

Watches and Autoalarms for Safety Purposes

§ 83.201 Watch required during silence periods.

(a) All ship stations employing telegraphy and normally keeping watch on frequencies in the authorized bands between 405 and 535 kHz shall, during their hours of service, take the necessary measures to insure an efficient watch by a duly licensed radiotelegraph operator on the international distress frequency 500 kHz for three minutes twice each hour, beginning at x h. 15 and x h. 45, Greenwich mean time (GMT). For this purpose, either headphones or a loudspeaker may be used, on condition that use of the loudspeaker is no less effective than use of headphones. While maintaining this watch, the operator shall not use or operate any radio equipment (such as, for examples, broadcast receivers, or amateur transmitters or receivers) not actually required for maritime mobile service.

(b) When in Regions 1 and 3 (except in the territorial waters of Japan and the Philippines) all ship stations employing telephony and normally keeping watch on frequencies in the authorized band between 1605 and 2850 kHz shall, during their hours of service, and as far as possible, take steps to keep watch on the international distress frequency 2182 kHz for 3 minutes twice each hour beginning at x h. 00 and x h. 30, Greenwich mean time.

§ 83.202 Watch required on vessels subject to the Communications Act.

(a) Each ship of the United States which is equipped with a radiotelegraph station for compliance with part II of title III of the Communications Act shall, while being navigated in the open sea outside of a harbor or port, keep a continuous and efficient watch on 500 kHz by means of radio officers: *Provided, however,* That in lieu thereof on a cargo ship equipped with a radiotelegraph auto alarm in proper operating condition an efficient watch on 500 kHz shall be maintained by means of a radio officer for at least 8 hours per day in the aggregate, i.e., for at least one-third of each day or portion of each day that the vessel is navigated in the open sea outside of a harbor or port.

(b) Each cargo ship of the United States which is equipped with a radio-telephone station for compliance with part II of title III of the Communications Act shall, while being navigated in the open sea outside of a harbor or port, keep a continuous and efficient watch on 2182 kHz in the room from which the vessel is normally steered while at sea, whenever such station is not being used for authorized traffic. Such watch shall be maintained by at least one officer or member of the crew of the vessel who has been designated by the master to do so. The person designated by the master may simultaneously perform other duties relating to the operation or navigation of the vessel, provided such other duties do not interfere with the effectiveness of the watch.

(c) Each vessel of the United States transporting more than six passengers for hire, which is equipped with a radio-telephone installation for compliance with part III of title III of the Communications Act shall, while being navigated in the open sea or any tidewater within the jurisdiction of the United States adjacent or contiguous to the open sea, keep a continuous and efficient watch on 2182 kHz in the case of an installation operating in the 1605–3500 kHz band, or on 156.8 MHz in the case of an installation operating in the 156–174 MHz band, whenever such installation is not being used for authorized traffic. Such watch shall be maintained by at least one officer or member of the crew of the vessel who has been designated by the master to do so. The person designated by the master may simultaneously perform other duties relating to the operation or navigation of the vessel, provided such other duties do not interfere with the effectiveness of the watch.

§ 83.203 Watch required on vessels subject only to the Safety Convention.

(a) Each ship of the United States which is equipped with a radiotelegraph station for compliance with the Safety Convention, but which is not fitted with a radiotelegraph auto alarm in proper operating condition, shall while at sea keep a continuous and efficient watch on 500 kHz by means of radio officers. If fitted with a radiotelegraph auto alarm in proper operating condition, such watch shall be kept while at sea as follows:

(1) Each cargo ship, and each passenger ship carrying or certificated to carry 250 passengers or less, or more than 250 passengers but engaged on a voyage of less than 16 hours duration between two consecutive ports, at least 8 hours watch a day in the aggregate;

(2) Each passenger ship carrying or certificated to carry more than 250 passengers and engaged on a voyage exceeding 16 hours duration between two consecutive ports, at least 16 hours watch a day in the aggregate.

(b) Each cargo ship of the United States which is equipped with a radio-telephone station for compliance with the Safety Convention shall, while at sea, keep a continuous and efficient watch on 2182 kHz in the manner prescribed by § 83.202(b).

§ 83.204 Provisions governing radiotelegraph watch.

(a) For the purpose of keeping the required radiotelegraph watch on 500 kHz the radio officer shall use the main or reserve receiver, and either headphones or a loudspeaker.

(b) While keeping this watch, the radio officer shall not use or operate any radio equipment (such as, for examples, broadcast receivers or amateur transmitters or receivers) not actually required for maritime mobile service.

(c) During the period of this watch, the radio officer may temporarily interrupt the required watch on 500 kHz while he is transmitting or receiving signals or messages to or from a station operating in the maritime mobile service, but only if it is not feasible to simultaneously handle such traffic and listen on 500 kHz by split headphones or a loudspeaker. The watch on 500 kHz shall, however, without exception be maintained by the radio officer during the silence periods.

§ 83.205 Compulsory use of radiotelegraph auto alarm.

The radiotelegraph auto alarm required to be fitted on board a cargo ship subject to the radiotelegraph provisions of part II of title III of the Communications Act or the Safety Convention and provided with but one radio officer, shall be in operation, connected to the main antenna and adjusted for optimum efficiency, at all times while the ship is being navigated in the open sea outside of a harbor or port when a radio officer, except under the circumstances as set forth in § 83.204(c), is not listening on the frequency 500 kHz.

* * * * * *

General Purpose Watches

§ 83.221 Watch on 500 kHz.

Ship stations using frequencies in the authorized bands between 405 and 535 kHz shall, during their hours of service, remain on watch on the calling frequency 500 kHz except when the operator is transmitting on 500 kHz, operating the ship station equipment on any other frequency authorized for transmission or reception in the maritime mobile service (including maintenance of the watch on 143 kHz as provided by § 83.222) if it is not possible for the operator to maintain at the same time, by any practicable means the watch for calls on 500 kHz. The term "by any practicable means" as used herein shall be construed to include the use of a loudspeaker or a head receiver energized by an additional radio receiver (other than the receiver actually in use for non-watch purposes) which is adjusted or tuned for effective reception on the radiochannel of which 500 kHz is the assigned frequency. The provisions of this section, however, shall not re-

lieve the ship from complying with the requirements for a safety watch as prescribed in §§ 83.201, 83.202, and 83.203.

§ 83.223 Watch on 2182 kHz.

(a) Each ship station on board a ship navigating the Great Lakes and licensed to transmit by telephony on one or more frequencies within the band 1605 to 3500 kHz shall, during its hours of service for telephony, maintain an efficient watch for reception of A3 and A3H emissions on the authorized carrier frequency 2182 kHz, whenever the station is not being used for transmission on that frequency or for communication on other frequencies.

(b) Except for stations on board vessels required by law to be fitted with radiotelegraph equipment, each ship station (in addition to those ship stations specified in paragraph (a) of this section) licensed to transmit by telephony on one or more frequencies within the band 1605 to 3500 kHz shall, during its hours of service for telephony, maintain an efficient watch for the reception of A3 and A3H emissions on the authorized carrier frequency 2182 kHz, whenever such station is not being used for transmission on that frequency or for communication on other frequencies. When the ship station is in Region 1 or 3, such watch shall, insofar as is possible, be maintained at least twice each hour for 3 minutes commencing at x h. 00 and x h. 30, Greenwich mean time.

§ 83.224 Watch on 156.800 MHz.

Each ship station, or, if more than one maritime mobile station is being operated from a vessel, then at least one station licensed to transmit by telephony on one or more frequencies within the band 156–162 MHz shall, during its hours of service for telephony in this band, maintain an efficient watch for the reception of F3 emissions on the frequency 156.800 MHz whenever such station is not being used for transmission on that frequency, or for communication on other frequencies in this band: *Provided, however,* That ship stations operating under the provisions of § 83.106(b)(5) or the note to § 83.106 of the rules are exempt from the watch requirements on 156.800 MHz.

Distress, Alarm, Urgency, and Safety

§ 83.231 Applicable regulations.

In addition to the governing provisions of the International Radio Regulations, Geneva, 1959 (see Article 36 thereof) applicable to the transmission and interception of distress, alarm, urgency, and safety signals and messages, mobile stations which are subject to this part shall be governed by this subpart in cases of distress, alarm, urgency, or safety transmissions.

§ 83.232 Authority for distress transmission.

No provision of the International Radio Regulations prevents the use by a mobile station in distress of any means at its disposal to attract attention, make known its position, and obtain help. A distress call and message, however, shall be transmitted only on the authority of the master or person responsible for the mobile station. No person shall knowingly transmit, or cause to be transmitted, any false or fraudulent signal of distress or communication relating thereto.

§ 83.233 Frequencies for use in distress.

In case of distress, mobile stations shall, in the bands set forth below, use the frequencies specified when requesting assistance from the maritime service. The preferred types of emission are shown. When a ship station cannot transmit on the designated frequency, it shall use any available frequency on which attention might be attracted.

Frequency band	Emission	Carrier frequency
405–535 kHz	A2	500 kHz[1]
1605–4000 kHz	A3, A3H	2182 kHz
118–136 MHz	A2, A3, A9	121.5 MHz
	A3	123.1 MHz
156–162 MHz	F3	156.8 MHz
225–399.9 MHz	A9	243 MHz

[1] The maximum transmitter power obtainable shall be used.

§ 83.234 Distress signals.

(a) The international radiotelegraph distress signal consists of the group "three dots, three dashes, three dots" (. . . — — — . . .), symbolized herein by $\overline{SOS}$, transmitted as a single signal in which the dashes are slightly prolonged so as to be distinguished clearly from the dots.

(b) The international radiotelephone distress signal consists of the word MAYDAY, pronounced as the French expression "m'aider".

(c) These distress signals indicate that a mobile station is threatened by grave and imminent danger and requests immediate assistance.

§ 83.235 Distress calls.

(a) The distress call sent by radiotelegraphy consists of:

(1) The distress signal $\overline{SOS}$, sent three times;

(2) The word DE;

(3) The call sign of the mobile station in distress, sent three times.

(b) The distress call sent by radiotelephony consists of:

(1) The distress signal MAYDAY spoken three times;

(2) The words THIS IS;

(3) The call sign (or name, if no call sign assigned) of the mobile station in distress, spoken three times.

(c) The distress call shall have absolute priority over all other transmissions. All stations which hear it shall immediately cease any transmission capable of interfering with the distress traffic and shall continue to listen on the frequency used for the emission of the distress call. This call shall not be addressed to a particular station and acknowledgment of receipt shall not be given before the distress message which follows it is sent.

§ 83.236 Distress messages.

(a) The radiotelegraph distress message consists of:

(1) The distress signal $\overline{SOS}$;

(2) The name of the mobile station in distress;

(3) Particulars of its position;

(4) The nature of the distress;

(5) The kind of assistance desired;

(6) Any other information which might facilitate rescue.

(b) The radiotelephone distress message consists of:

(1) The distress signal MAYDAY;

(2) The name of the mobile station in distress;

(3) Particulars of its position;

(4) The nature of the distress;

(5) The kind of assistance desired;

(6) Any other information which might facilitate

rescue (for example, the length, color, and type of vessel; number of persons on board, etc.).

(c) As a general rule, a ship shall signal its position in latitude and longitude (Greenwich), using figures for the degrees and minutes, together with one of the words NORTH or SOUTH and one of the words EAST or WEST. In radiotelegraphy, the signal . — . — . — shall be used to separate the degrees from the minutes. When practicable, the true bearing and distance in nautical miles from a known geographical position may be given.

§ 83.237 Radiotelegraph distress call and message transmission procedure.

(a) The radiotelegraph distress procedure shall normally consist of the following six steps; however, when time is vital, the second step of this procedure, or even the first and second steps, may be omitted. These two steps of the distress procedure may also be omitted in circumstances where transmission of the alarm signal is considered unnecessary:

(1) The radiotelegraph alarm signal;

(2) The distress call and an interval of two minutes;

(3) The distress call;

(4) The distress message;

(5) Two dashes of ten to fifteen seconds each;

(6) The call sign of the mobile station in distress.

(b) The radiotelegraph distress transmissions shall be sent by means of the International Morse Code at a speed not exceeding 16 words per minute nor less than 8 words per minute.

(c) The distress message, preceded by the distress call, shall be repeated at intervals, especially during the 500 kHz international silence periods, until an answer is received. The radiotelegraph alarm signal may also be repeated, if necessary.

(d) The transmissions under paragraph (a) (5) and (6) of this section, which are to permit direction finding stations to determine the position of the station in distress may be repeated at frequent intervals if necessary.

(e) When the mobile station in distress receives no answer to a distress message transmitted on the distress frequency, the message may be repeated on any other available frequency on which attention might be attracted.

§ 83.238 Radiotelephone distress call and message transmission procedure.

(a) The radiotelephone distress procedure shall consist of:

(1) The radiotelephone alarm signal (whenever possible);

(2) The distress call;

(3) The distress message.

(b) The radiotelephone distress transmissions shall be made slowly and distinctly, each word being clearly pronounced to facilitate transcription.

(c) After the transmission by radiotelephony of its distress message, the mobile station may be requested to transmit suitable signals followed by its call sign or name, to permit direction-finding stations to determine its position. This request may be repeated at frequent intervals if necessary.

(d) The distress message, preceded by the distress call, shall be repeated at intervals until an answer is received. This repetition shall be preceded by the radiotelephone alarm signal whenever possible.

(e) When the mobile station in distress receives no answer to a distress message transmitted on the distress frequency, the message may be repeated on any other available frequency on which attention might be attracted.

§ 83.239 Acknowledgment of receipt of distress message.

(a) Stations of the maritime mobile service which receive a distress message from a mobile station which is, beyond any possible doubt, in their vicinity, shall immediately acknowledge receipt. However, in areas where reliable communication with one or more coast stations are practicable, ship stations may defer this acknowledgement for a short interval so that a coast station may acknowledge receipt.

(b) Stations of the maritime mobile service which receive a distress message from a mobile station which, beyond any possible doubt, is not in their vicinity, shall allow a short interval of time to elapse before acknowledging receipt of the message, in order to permit stations nearer to the mobile station in distress to acknowledge receipt without interference.

§ 83.240 Form of acknowledgment.

(a) The acknowledgement of receipt of a distress message is transmitted, when radiotelegraphy is used, in the following form:

(1) The call sign of the station sending the distress message, sent three times;

(2) The word DE;

(3) The call sign of the station acknowledging receipt, sent three times;

(4) The group RRR;

(5) The distress signal $\overline{\text{SOS}}$

(b) The acknowledgment of receipt of a distress message is transmitted, when radiotelephony is used, in the following form:

(1) The call sign or other identification of the station sending the distress message, spoken three times;

(2) The words THIS IS;

(3) The call sign or other identification of the station acknowledging receipt, spoken three times;

(4) The word RECEIVED;

(5) The distress signal MAYDAY.

§ 83.241 Information furnished by acknowledging station.

(a) Every mobile station which acknowledges receipt of a distress message shall, on the order of the master or person responsible for the ship, aircraft, or other vehicle carrying such mobile station, transmit as soon as possible the following information in the order shown:

(1) Its name;

(2) Its position, in the form prescribed in § 83.236(c);

(3) The speed at which it is proceeding towards, and the approximate time it will take to reach, the mobile station in distress.

(b) Before sending this message, the station shall ensure that it will not interfere with the emissions of other stations better situated to render immediate assistance to the station in distress.

§ 83.242 Transmission of distress message by a station not itself in distress.

(a) A mobile station or a land station which learns that a mobile station is in distress shall transmit a distress message in any of the following cases:

(1) When the station in distress is not itself in a position to transmit the distress message;

(2) When the master or person responsible for the ship, aircraft, or other vehicle not in distress, or the person responsible for the land station, considers that further help is necessary;

(3) When, although not in a position to render assistance, it has heard a distress message which has not been acknowledged. When a mobile station transmits a distress message under these conditions, it shall take all necessary steps to notify the authorities who may be able to render assistance.

(b) The transmission of a distress message under the conditions prescribed in paragraph (a) of this section shall be made on either or both of the international distress frequencies (500 kHz radiotelegraph; 2182 kHz radiotelephone) or on any other available frequency on which attention might be attracted.

(c) The transmission of the distress message shall always be preceded by the call indicated below, which shall itself be preceded whenever possible by the radiotelegraph or radiotelephone alarm signal. This call consists of:

(1) When radiotelegraphy is used:

(i) the signal DDD SOS SOS SOS DDD;

(ii) The word DE;

(iii) The call sign of the transmitting station, sent three times.

(2) When radiotelephony is used:

(i) The signal MAYDAY RELAY, spoken three times;

(ii) The words THIS IS;

(iii) The call sign or other identification of the transmitting station, spoken three times.

(d) When the radiotelegraph alarm signal is used, an interval of two minutes shall be allowed, whenever this is considered necessary, before the transmission of the call mentioned in subparagraph (c)(1) of this section.

§ 83.243 Control of distress traffic.

(a) Distress traffic consists of all messages relating to the immediate assistance required by the mobile station in distress. In distress traffic, the distress signal shall be sent before the call and at the beginning of the preamble of any radiotelegram.

(b) The control of distress traffic is the responsibility of the mobile station in distress or of the station which, pursuant to § 83.242(a), has sent the distress message. These stations may, however, delegate the control of the distress traffic to another station.

(c) The station in distress or the station in control of distress traffic may impose silence either on all stations of the mobile service in the area or on any station which interferes with the distress traffic. It shall address these instructions "to all stations" or to one station only, according to circumstances. In either case, it shall use:

(1) In radiotelegraphy, the abbreviation QRT, followed by the distress signal SOS. The use of the signal QRT SOS shall be reserved for the mobile station in distress and for the station controlling distress traffic;

(2) In radiotelephony, the signal SEELONCE MAYDAY. The use of this signal shall be reserved for the mobile station in distress and for the station controlling distress traffic.

(d) If it is believed to be essential, any station of the mobile service near the ship, aircraft, or other vehicle in distress, may also impose silence. It shall use for this purpose:

(1) In radiotelegraphy, the abbreviation QRT, followed by the word DISTRESS and its own call sign;

(2) In radiotelephony, the word SEELONCE, followed by the word DISTRESS and its own call sign or other identification.

§ 83.244 Notification of resumption of normal working.

(a) When distress traffic has ceased, or when silence is no longer necessary on a frequency which has been used for distress traffic, the station which has controlled this traffic shall transmit on that frequency a message addressed "to all stations" indicating that normal working may be resumed.

(1) In radiotelegraphy, this message consists of:

(i) The distress signal SOS;

(ii) The call "to all stations" (CQ), sent three times;

(iii) The word DE;

(iv) The call sign of the station sending the message;

(v) The time of handing in of the message;

(vi) The name and call sign of the mobile station which was in distress;

(vii) The service abbreviation QUM.

(2) In radiotelephony, this message consists of:

(i) The distress signal MAYDAY;

(ii) The call "to all stations", spoken three times;

(iii) The words THIS IS;

(iv) The call sign or other identification of the station sending the message;

(v) The time of handing in of the message;

(vi) The name and call sign of the mobile station which was in distress;

(vii) The words SEELONCE FEENEE.

(b) Until they receive the foregoing message indicating that normal working may be resumed, all stations which are aware of the distress traffic, and which are not taking part in it, are forbidden to transmit on the frequencies on which the distress traffic is taking place.

§ 83.245 Radiotelegraph and radiotelephone alarm signals.

(a) The international radiotelegraph alarm signal consists of a series of twelve dashes sent in one minute, the duration of each dash being four seconds and the duration of the interval between consecutive dashes one second. The purpose of this special signal is the actuation of automatic devices giving the alarm to attract the attention of the operator when there is no listening watch on the distress frequency.

(b) The international radiotelephone alarm signal consists of two substantially sinusoidal audio frequency tones transmitted alternately. One tone shall have a frequency of 2200 hertz and the other a frequency of 1300 hertz, the duration of each tone being 250 milliseconds. When generated by automatic means, the radiotelephone alarm signal shall be transmitted continuously for a period of at least 30 seconds, but not exceeding one minute; when generated by other means, the signal shall be transmitted as continuously as practicable over a period of approximately one minute. The purpose of this special signal is to attract the attention of the person on watch or to actuate automatic devices giving the alarm.

§ 83.246 Use of alarm signals.

(a) The radiotelegraph or radiotelephone alarm signal, as appropriate, shall only be used to announce:

(1) That a distress call or message is about to follow;

(2) The transmission of an urgent cyclone warning. In this case the alarm signal may only be used by coast stations authorized by the Commission to do so; or

(3) The loss of a person or persons overboard. In

this case the alarm signal may only be used when the assistance of other ships is required and cannot be satisfactorily obtained by the use of the urgency signal only, but the alarm signal shall not be repeated by other stations. The message shall be preceded by the urgency signal.

(b) In cases described in subparagraphs (2) and (3) of paragraph (a) of this section, the transmission of the warning or message by radiotelegraphy shall not begin until two minutes after the end of the radiotelegraph alarm signal.

§ 83.247 Urgency signals.

(a) The urgency signal indicates that the calling station has a very urgent message to transmit concerning the safety of a ship, aircraft, or other vehicle, or the safety of a person. The urgency signal shall be sent only on the authority of the master or person responsible for the mobile station.

(b) In radiotelegraphy, the urgency signal consists of three repetitions of the group XXX, sent with the individual letters of each group, and the successive groups clearly separated from each other. It shall be transmitted before the call.

(c) In radiotelephony, the urgency signal consists of the word PAN, spoken three times and transmitted before the call.

(d) The urgency signal shall have priority over all other communications, except distress. All mobile and land stations which hear it shall take care not to interfere with the transmission of the message which follows the urgency signal.

§ 83.248 Urgency message.

(a) The urgency signal and call, and the message following it, shall be sent on one of the international distress frequencies (500 kHz radiotelegraph; 2182 kHz radiotelephone), or on the national distress frequency (156.800 MHz radiotelephone). However, stations which cannot transmit on a distress frequency may use any other available frequency on which attention might be attracted.

(b) Mobile stations which hear the urgency signal shall continue to listen for at least three minutes. At the end of this period, if no urgency message has been heard, they may resume their normal service. However, land and mobile stations which are in communication on frequencies other than those used for the transmission of the urgency signal and of the call which follows it may continue their normal work without interruption provided the urgency message is not addressed "to all stations" (CQ).

(c) When the urgency signal has been sent before transmitting a message "to all stations" (CQ) and which calls for action by the stations receiving the message, the station responsible for its transmission shall cancel it as soon as it knows that action is no longer necessary. This message of cancellation shall likewise be addressed "to all station" (CQ).

§ 83.249 Safety signals.

(a) The safety signal indicates that the station is about to transmit a message concerning the safety of navigation or giving important meteorological warnings.

(b) In radiotelegraphy, the safety signal consists of three repetitions of the group TTT, sent with the individual letters of each group, and the successive groups clearly separated from each other. It shall be sent before the call.

(c) In radiotelephony, the safety signal consists of the word SECURITY, spoken three times and transmitted before the call.

(d) The safety signal and call shall be sent on one of the international distress frequencies (500 kHz radiotelegraph; 2182 kHz radiotelephone), or on the national distress frequency (156.800 MHz radiotelephone). However, stations which cannot transmit on a distress frequency may use any other available frequency on which attention might be attracted.

§ 83.250 Safety message.

(a) The safety signal and call shall be followed by the safety message. Where practicable, the safety message should be sent on a working frequency, and a suitable announcement to this effect shall be made at the end of the call.

(b) Except for the cases mentioned in paragraph (c) of this section, the safety signal when sent on the frequency 500 kHz shall be transmitted towards the end of the first available period of silence; the safety message shall be transmitted immediately after the period of silence.

(c) Messages containing meteorological warnings, or containing information concerning the presence of cyclones, dangerous ice, dangerous wrecks, or any other imminent danger to marine navigation, shall be preceded by the safety signal and transmitted with the least possible delay to other mobile stations in the vicinity, and to the appropriate authorities at the first point of the coast with which contact can be established.

(d) All stations hearing the safety signal shall listen to the safety message until they are satisfied that the message is of no concern to them. They shall not make any transmission likely to interfere with the message.

§ 83.251 Bridge-to-bridge communication procedure.

(a) Notwithstanding § 83.178, vessels, dredges, and floating plants subject to the Vessel Bridge-to-Bridge Radiotelephone Act transmitting on the designated navigational frequency shall initiate communications on this frequency in a format similar to those given below:

(1) This is the (name of vessel). My position is (give readily identifiable position and, if useful, course and speed) about to (describe contemplated action). Out.

(2) Vessel off (give a readily identifiable position). This is (name or vessel) off (give a readily identifiable position). I plan to (give proposed course of action). Over.

(3) (Coast station), This is (vessel's name) off (give readily identifiable position). I plan to (give proposed course of action). Over.

(b) Vessels acknowledging receipt shall answer "(Name of vessel calling). This is (Name of vessel answering). Received your call" and follow with an indication of their intentions. Communications shall terminate when each ship is satisfied that the other no longer poses a threat to its safety and is ended with "Out".

(c) Use of power greater than 1 watt in a bridge-to-bridge station shall be limited to the following three situations:

(1) Emergency.

(2) Failure of the vessel being called to respond to a second call at low power.

(3) A broadcast call as in paragraph (a) (1) of this section in a blind situation, e.g., rounding a bend in a river.

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Message Charges

§ 83.271 Distress messages.

No charge shall be made by any ship or station in the mobile service of the United States for the transmission of distress messages and replies thereto in connection with situations involving the safety of life and property at sea.

§ 83.272 Danger messages.

No charge shall be made by any ship station or other station in the maritime mobile service of the United States for the transmission, receipt, or relay of the information concerning dangers to navigation designated in § 83.303(b), originating on a ship of the United States or of a foreign country.

§ 83.273 Tariff filing required.

No charge shall be made for the service of any station on board ship subject to this part unless effective tariffs applicable to such service are on file with the Commission, pursuant to the requirements of section 203 of the Communications Act and Part 61 of this chapter.

§ 83.274 Responsibility for payment.

(a) Each ship station shall be responsible for the payment of all charges accruing to any other station (s) or facilities for the handling or forwarding of messages or communications transmitted by that station.

(b) The transmission by any ship station of information concerning dangers to navigation, made in compliance with the provisions of § 83.303(b), to any station which imposes a charge for the reception, relay, or forwarding of the required information, shall be free of cost to the ship concerned and any communication charges incurred by the ship for transmission, relay, or forwarding of the information may be certified to the Commission for reimbursement out of moneys appropriated to the Commission for that purpose.

§ 83.275 Ship position reports.

Any common carrier subject to the Communications Act may furnish reports of positions of ships at sea to newspapers of general circulation, either at a nominal charge or without charge, provided the name of such common carrier is displayed along with such ship position reports.

§ 83.276 Free safety service.

Notwithstanding any other provision of law, any ship station may render free service in connection with situations involving the safety of life and property, including hydrographic reports, weather reports, reports regarding aids to navigation and medical assistance to injured or sick persons on ships and aircraft at sea: *Provided*, That the Commission, from time to time under particular circumstances, may impose specific limitations on such free service to the extent that it finds desirable in the public interest.

§ 83.277 Free service for national defense.

Any common carrier subject to the Communications Act may render to any agency of the United States Government free service in connection with the preparation for the national defense. Every such carrier rendering any such free service shall make and file in duplicate, with the Commission, on or before the 31st day of July and on or before the 31st day of January in each year, reports covering the periods of 6 months ending on the 30th day of June and the 31st day of December, respectively, next prior to said dates. These reports shall show the names of the agencies to which free service was rendered pursuant to this paragraph, the general character of the communications handled for each agency, and the charges in dollars which would have accrued to the carrier for such service rendered to each agency if charges for all such communications had been collected at the published tariff rates.

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Use of Radiotelegraphy

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§ 83.316 Frequencies in the bands, 90–160 kHz and 405–535 kHz available to ship stations for radiotelegraphy.

(a) 90–160 kHz:

kHz	*kHz*
152	156
153	157
154	158
155	

(b) 405–535 kHz:

kHz	*kHz*
[1] 410	480
425	500 Calling and distress
[1] 444	[1] 512
454	
468	

[1] Subject to the special conditions and limitations set forth in paragraph (c) of this section.

(c) (1) Except for distress communication, the frequency 444 kHz is for communication with U.S. Government stations only. Its use is subject to the condition that harmful interference is not caused to the service of any coast station.

(2) The frequency 410 kHz may be used for radiodetermination and for communication by radiotelegraph with direction finding stations concerning radiodetermination.

(3) The frequency 512 kHz may be used by ship stations:

(i) As a supplementary calling frequency when 500 kHz is being used for distress purposes;

(ii) As a working frequency, except in those areas where it is in use as a supplementary calling frequency when 500 kHz is being used for distress purposes.

§ 83.317 High traffic ship radiotelegraph working frequencies.

(a) High traffic ship radiotelegraph working frequencies in the bands between 4 and 23 MHz are set forth in Table 1a. Application may be made for two

high traffic ship working frequency column symbols from the "H" series, which includes one or more frequencies in each of the 4, 6, 8, 12, 16, and 22 MHz bands. If more than two symbols of the "H" series are allocated for a particular licensee, the frequency symbols should be applied for in rotation for successive vessels as for calling frequencies (see § 83.318), except that the first symbol for each vessel must be the one after the last of the series of two or more symbols of the previous vessel.

HIGH TRAFFIC SHIP RADIOTELEGRAPH WORKING FREQUENCIES (kHz)

Symbol	4 MHz (kHz)	6 MHz (kHz)	8 MHz (kHz)	12 MHz (kHz)	16 MHz (kHz)	22 MHz (kHz)
H1	4172.5	6258.75	8342 8343 8344 8348	12503.5 12513 12514.5 12516 12517.5	16662 16674 16684 16686 16688 16690	22189 22218
H2	4173.5	6260.25	8342 8343 8344 8347	12505.5 12513 12514.5 12516 12520.5	16662 16674 16684 16686 16688 16694	22191 22219
H3	4174	6261	8342 8343 8344 8348	12511.5 12513 12514.5 12516 12522	16656 16662 16684 16686 16688 16696	22195 22219
H4	4175	6262.5	8342 8343 8344 8350	12504 12513 12514.5 12516 12525	16670 16672 16684 16686 16688 16700	22197 22209
H5	4175.5	6263.25	8342 8343 8344 8351	12507 12513 12514.5 12516 12526.5	16668 16676 16684 16686 16688 16702	22201 22213
H6	4176.5	6264.75	8342 8343 8344 8353	12505.5 12513 12514.5 12516 12529.5	16662 16674 16684 16686 16688 16706	22215 22187
H7	4177	6265.5	8342 8343 8344 8354	12510 12513 12514.5 12516 12531	16664 16680 16684 16686 16688 16708	22207 22193
H8	4177.5	6266.25	8342 8343 8344 8355	12511.5 12513 12514.5 12516 12532.5	16666 16682 16684 16686 16688 16710	22213 22199
H9	4173	6259.5	8342 8343 8344 8346	12504 12513 12514.5 12516 12519	16670 16672 16684 16686 16688 16692	22221 22205
H10	4174.5	6261.75	8342 8343 8344 8349	12507 12513 12514.5 12516 12523.5	16668 16676 16684 16686 16688 16698	22221 22211
H11	4176	6264	8342 8343 8344 8352	12508.5 12513 12514.5 12516 12528	16662 16678 16684 16686 16688 16704	22203 22217

§ 83.322 Frequencies for use in distress.

(a) The international distress frequency is 500 kHz; it is used as an assigned frequency for this purpose by ship, survival craft, or aircraft stations using frequencies in the band 405–535 kHz, when requesting assistance from the maritime services. It is used, preferably with A2 emission, for the distress call, distress traffic and for the transmission of urgent and safety messages.

(b) The frequency 8364 kHz is for use by survival craft stations equipped to transmit within the band 4000-27,500 kHz and desiring to establish with stations of the maritime and aeronautical mobile services communications relating to search and rescue operations.

(c) The frequency 121.5 MHz (using class A2 emission) is available for radiobeacon purposes to survival craft stations. The frequency 121.5 MHz (using A9 emission) is available to emergency position indicating radiobeacon (EPIRB) stations for facilitating search and rescue operations. The frequency 121.5 MHz (class A3 emission) is available to authorized ship stations for emergency communications between ships and aircraft only if operation on the auxiliary frequency 123.1 MHz is also provided for. The frequency 121.5 is available to authorized ship stations for A3 emission for emergency communications between ships and aircraft involved in coordinated search and rescue operations when other VHF channels are not available.

As soon as practicable after establishing contact on 121.5 MHz ships and aircraft engaged in the search and rescue operation should shift to the auxiliary frequency 123.1 MHz. The universal auxiliary frequency 123.1 MHz is available to mobile stations engaged in scene of action search and rescue operations as the auxiliary to the emergency clear channel frequency 121.5 MHz.

(d) The frequency 243 MHz (class A9 emission only) is available to EPIRB stations for facilitating search and rescue operations.

§ 83.323 Frequencies for call and reply.

(a) (1) The frequency 500 kHz is the general international calling frequency which shall be used by any ship station engaged in radiotelegraphy in the authorized band 405–535 kHz and by aircraft desiring to enter into communication with a station of the maritime mobile service using frequencies in this band;

(2) The frequency for replying to a call sent on the general calling frequency is 500 kHz, except where the calling station requests that the reply be made on an authorized working frequency. In Region 2, and in other areas of heavy traffic, ship stations should request coast stations to answer on their normal working frequency;

(3) In order to facilitate the reception of distress calls, all transmissions on 500 kHz shall be reduced to a minimum. Preparatory operating signals or brief communications concerning the operation of the station may be included on 500 kHz provided the overall duration of the transmission is not longer than 10 seconds. Transmissions of longer duration shall be made on the working frequency.

(b) In Region 3, the band 2089.5–2092.5 kHz is the calling and safety band for the maritime mobile service of radiotelegraphy in those parts of the bands between 1605 and 2085 kHz in which radiotelegraphy is authorized. Frequencies in the band 2089.5–2092.5 kHz may be used for calls, replies, and safety. These frequencies may also be used for messages preceded by the urgency or safety signals.

(c) In Region 2, the frequency 2091 kHz is the international calling frequency for ship stations using telegraphy within the band 2089.5–2092.5 kHz. It shall be used for call, reply and signals preparatory to traffic by all ship stations using telegraphy to establish communication with other ship stations operating in the band 2089.5–2092.5 kHz or with coast stations using telegraphy and operating in the band 2035–2065 kHz; *Provided*, That transmission by ship stations for this purpose on any calling frequency within the band 2089.5–2092.5 kHz is permissible as a practical operating procedure to minimize interference in lieu of transmission on the frequency 2091 kHz. A ship station, after establishing communication on a calling frequency, except safety and distress, shall change to an authorized working frequency in the bands between 4 and 23 MHz for the transmission of traffic.

* * * * * *

§ 83.325 Use of Morse Code required.

The signal code employed for telegraphy by stations in the maritime mobile service shall be the Morse Code signals specified in the Telegraph Regulations annexed to the International Telecommunication Convention, Geneva, 1959. However, for radiotelegraph communication of a special character, the use of other signals may be specifically authorized by the Commission in response to an appropriate application therefor.

§ 83.326 Identification of stations.

(a) All radiotelegraph emissions of a ship station or a survival craft station shall be clearly identified by transmission therefrom of the official call letters assigned to that station for telegraphy by the Commission. These call letters shall be transmitted by telegraphy in accordance with § 83.325 and the procedure set forth in the International Radio Regulations and by means of the class of emission normally used by the station for telegraphy: *Provided*, That they shall be transmitted at intervals not exceeding 15 minutes whenever transmission is sustained for a period exceeding 15 minutes, except when a ship station is engaged in transmitting public correspondence communications the identification may be deferred until completion of each communication with any other station.

(b) The requirements of this section do not apply to survival craft stations when transmitting distress signals automatically or when operating on 121.5 MHz for radiobeacon purposes.

(c) Emergency position indicating radiobeacon stations do not require identification.

* * * * * *

§ 83.328 Radiotelegraph operating procedure.

(a) Except for the transmission of distress or urgency signals, all transmissions from stations on board ship must cease within the band 485–515 kHz during each 500 kilohertz silence period, i.e., for three minutes twice an hour beginning at x h. 15 and x h. 45, Greenwich mean time.

(b) In order to facilitate radiotelegraph communication in the maritime mobile service, all ship stations transmitting by means of telegraphy shall, whenever practicable, use the service abbreviations ("Q" signals) listed in Appendix 13 to the International Radio Regulations, Geneva, 1959.

(c) In addition to compliance with all applicable sections of this part, the operation of ship stations using telegraphy for call, reply, and the transmission of message traffic shall, in particular, comply with all applicable provisions of Articles 29, 30, 31, 37, 38, and 39 of the International Radio Regulations, Geneva, 1959.

* * * * * *

§ 83.329 Station documents.

(a) The compulsorily fitted ship radiotelegraph station shall be provided with the following documents:

(1) A valid station license;

(2) The necessary operator license(s);

(3) The station log required by this part for stations of this category;

(4) The Alphabetical List of Call Signs of Stations used by the Maritime Mobile Service;

(5) The List of Coast Stations;

(6) The List of Ship Stations;

(7) The List of Radiodetermination and Special Service Stations;

(8) The Manual for use by the Maritime Mobile Service, published by the International Telecommunication Union, Geneva;

NOTE: The Additional Radio Regulations contained in Part B of the Manual do not apply to ships of U.S. registry.

(9) Part 83 of this chapter.

(b) All ship stations on board ships not compulsorily fitted with a radiotelegraph installation, but using telegraphy, shall be provided with the documents pre-

scribed by subparagraphs (1), (2), (3), (4), (5), (6), (8), and (9) of paragraph (a) of this section.

(c) These documents shall be continuously and readily available to the licensed operator on duty during the hours of service of the station.

§ 83.330 Station logs.

(a) (1) Each ship station authorized to use telegraphy on frequencies within the band 90 to 535 kHz shall maintain an accurate radiotelegraph log. The first page of each portion of the log covering each voyage shall consist of a "title page" which, upon completion of all entries for the particular voyage, shall contain the following information:

(i) Name of ship and call letters of ship station;

(ii) Period of time covered by such portion of the log;

(iii) Number of pages constituting such portion of the log;

(iv) A statement as to whether or not such portion of the log contains distress entries; if so, the pages containing such entries shall be designated;

(v) Operator's signature, mailing address, and radio operator license data (number, class, and date of issuance).

(2) In addition, the log shall be maintained as follows:

(i) Each sheet of the log shall be numbered in sequence, for each voyage, and shall include the name of the vessel, official call letters of the ship station and the name of the operator on watch.

(ii) The entry "on watch" shall be made by the operator beginning a watch, followed by his signature. The entry "off watch" shall be made by the operator being relieved or terminating a watch, followed by his signature. All log entries shall be currently completed at the end of each watch by the operator responsible for the entries. The use of initials or signs is not authorized in lieu of the operator's signature.

(3) During the period a watch is maintained by an operator, all calls transmitted to or from the ship station and all replies transmitted or received shall be entered, stating the time and frequencies, and the call letters of the station communicated with or heard. (If desired, the names of the stations or ships also may be entered.) In addition, a notation of any messages exchanged shall be entered stating the time, the frequency in kilohertz, and the call letters of the station(s) heard, or communicated with. (If desired, the names of the stations or ships also may be entered.) In so far as possible, a positive entry with respect to reception on 500 kHz shall be made at least once in each 15 minutes. The entries required by subparagraph (5) of this paragraph shall be acceptable as positive entries: *Provided*, Operating conditions are such as to prevent additional entries being made.

(4) The date and time of each occurence or incident required to be entered in the log shall be shown opposite the entry and the time shall be expressed in Greenwich mean time (GMT),[1] except that in the Great Lakes region the time shall be expressed in eastern standard time (e.s.t.) (counted from 0000 to 2400 o'clock beginning at midnight). The first entry in each hour shall consist of four figures; additional entries in the same hour may be expressed in two figures by omitting the hour designation. The abbreviation "GMT" (e.s.t. in the Great Lakes region) shall be marked at the head of the column in which the time is entered.

(5) During the period a watch is maintained by an operator, an entry shall be made twice per hour stating whether or not the international silence period was observed. In addition, entries shall be made indicating any signals or communications heard on 500 kilohertz during this period. If no signals are heard on 500 kHz, an entry to that effect shall be made. The use of rubber stamps for making entries to show observation of the silence period is not authorized.

(6) All distress calls, automatic-alarm signals, urgent and safety signals made or intercepted, the complete text, if possible, of distress messages and distress communications, and any incidents or occurrences which may appear to be of importance to safety of life or property at sea, shall be entered, together with the time of such observation or occurrence, and the position of the ship or other mobile unit in need of assistance, if it can be determined.

(7) Whenever harmful interference is experienced, an entry shall be made to that effect, stating the source of the interference, if known.

(8) The approximate geographical location of the ship, preferably the noon position, shall be entered each day of each voyage, either in terms of latitude and longitude, or as the distance in nautical miles and the direction from a known fixed point. For this purpose, the master of the ship shall furnish this information to the radio operator. The position report so furnished shall correspond to any entry of the same position made in other official records of the ship.

(9) An entry shall be made of the date and time of departure and arrival of the vessel at each port, including in each entry the name of the port.

(10) A daily entry shall be made regarding comparison of the radio station clock with standard time, including an indication of any errors observed and corrections made. For this purpose, authentic radio time signals received from land or fixed stations shall be acceptable as standard time.

(11) All test transmissions shall be entered, together with the time of such transmissions and the approximate geographical location of the vessel, without regard to whether two-way communication with any other station is established.

(12) Any failure of equipment to operate as required, any failure of power supply, any inability to obtain sufficient power to charge storage batteries or to properly operate the radio installation and any incidents tending to unduly delay communications shall be entered.

(b) In addition to the radio log requirements stipulated in paragraph (a) of this section, the radio log of each ship station authorized to use telegraphy on frequencies within the band 90 to 535 kHz, shall, when the ship is required by law and regulations to keep a radiotelegraph watch on 500 kHz for safety purposes by means of a qualified operator, comply also with the following provisions:

(1) Entries shall be made of the results of tests of the emergency installation including transmitter antenna current, hydrometer readings of lead-acid storage batteries, voltage readings of other types of batteries, and quantity of fuel available for engine generators.

(2) An entry shall be made each time the emergency power supply is used (when the vessel is in the open sea) to carry on communication (other than a watch for safety purposes), stating the approximate period of time of such use.

[1] For example, 8:01 p.m. eastern standard time should be entered as 0101 GMT; 8:30 a.m. eastern standard time should be entered as 1330 GMT; 7:45 p.m. eastern standard time should be entered as 0045 GMT.

(3) Results of inspections and tests of survival craft radio equipment, when installed in compliance with requirements of law, prior to departure of the vessel from a harbor or port and the results of weekly inspections of such survival craft equipment shall be entered.

(4) On a cargo vessel equipped with an auto alarm, the entry "auto alarm on", and the entry "auto alarm off", respectively, shall be made whenever the operator places the auto alarm in and out of operation. Results of the required auto alarm tests shall be entered daily, including the minimum number of 4-second dashes from the testing device which were necessary to properly operate the alarm.

(5) On a cargo vessel equipped with an auto-alarm, an entry shall be made in the radio station log whenever the visual indicator installed on the bridge (to indicate when the alarm becomes inoperative due to prolonged atmospherics or other interference), remains actuated for a continuous period of 5 minutes. A statement shall be included giving particulars as to the time the operator was called to make the necessary repairs or adjustments; any reason for the failure; the names of any parts removed, added, or substituted; repairs effected; and the time the alarm was restored to proper operating conditions.

(6) On a cargo vessel equipped with an auto-alarm, an entry shall be made in the radio station log whenever the auto-alarm becomes inoperative due to causes not indicated by the audible warning or the visual indicator, or whenever the audible warning is actuated. The entry shall include a statement showing the time the operator was called to make any necessary repairs or adjustments; the reason for the audible alarm being actuated or failing to be actuated, any parts removed, added, or substituted; repairs effected; and the time the auto-alarm was restored to proper operating condition.

(7) A daily entry shall be made while the ship is at sea showing whether the storage batteries forming part of the main installation or the emergency installation were brought up to the normal full charged condition that day.

(8) Entries shall be made stating when each storage battery used as the power supply for the main and emergency installations is placed on charge or off charge.

(9) Entries shall be made stating details of maintenance of survival craft radio equipment, including a record of charging of any storage batteries supplying power to such equipment. The record of charging shall show when such storage battery is placed on charge and when it is taken off charge.

(c) Each ship station authorized to use telegraphy, on frequencies above 550 kHz exclusively (except ship stations on the Great Lakes and on board vessels navigated solely on inland waters of the United States), shall maintain an accurate radiotelegraph log as prescribed in paragraph (a) of this section: *Provided*, That paragraph (a) (3) and (5) of this section shall, in this case, not be applicable.

(d) Each ship station on the Great Lakes and on board a vessel navigated solely on inland waters of the United States which is authorized to use telegraphy, on frequencies above 550 kHz exclusively, shall maintain an accurate radiotelegraph log as follows:

(1) Each sheet of the log shall be numbered in sequence and shall include the name of the vessel, official call letters of the ship station and the signature of the licensed operator in attendance at the time communication is effected.

(2) An entry shall be made for each complete exchange of communications with any station, stating the approximate geographical location of the vessel, the call letters or the name of the station communicated with, the time of the communication, the nature of the messages or signals exchanged, and designation of the transmitting frequencies.

(3) All test transmissions shall be entered, including designation of the transmitting frequency, together with the time of commencement and completion of such transmissions and the approximate geographical location of the vessel without regard to whether two-way communication with any other station is established.

(4) All distress calls, urgent and safety signals made or intercepted; the complete text, if possible, of distress messages and distress communication; and any incidents or occurrences which may appear to be of importance to safety of life or property shall be entered, together with the time of such observation of occurrence, designation of the frequency on which such transmissions were received, and the position of the ship or other mobile unit in need of assistance, if it can be determined.

(5) Any failure of equipment to operate as required, any failure of power supply, any inability to obtain power to charge storage batteries or to properly operate the radio installation and any incidents tending to unduly delay communication shall be entered.

(6) The date and time of making an entry shall be shown opposite the entry and the time shall be expressed as follows:

(i) For vessels navigated on the Great Lakes:

Eastern standard time (e. s. t.) (counted from 0000 to 2400 o'clock beginning at midnight).[1] The first entry in each hour shall consist of four figures; additional entries in the same hour may be expressed in two figures by omitting the hour designation. The abbreviation "e. s. t." shall be marked at the head of the column in which the time is entered.

(ii) For vessels navigated on inland waters of the United States, other than the Great Lakes:

Local standard time (e. s. t., c. s. t., etc.) counted from 0000 to 2400 o'clock, beginning at midnight).[1] The first entry in each hour shall consist of four figures; additional entries in the same hour may be expressed in two figures by omitting the hour designation. The abbreviation "e. s. t." or "c. s. t.", etc., shall be marked at the head of the column in which the time is entered. However, this provision shall not prohibit the use of time entries expressed in GMT (and so indicated) in lieu of local standard time.

(e) The ship radiotelegraph log currently in use shall be kept by the licensed operator(s) of the station and while in use it shall be located in the radiotelegraph operating room of the ship. At the conclusion of each voyage terminating at a port of the United States, the original station log or duplicate thereof dating from the last departure of the ship from a United States port shall be retained under proper custody on board the ship for a sufficient period of time, but not necessarily in excess of 24 hours, to be **available for inspection by a duly authorized representative of the Commission. Thereafter the original log, and the duplicate log, if provided, may be filed at an established shore office of the ship station licensee, and shall be retained as stipulated by § 83.115.**

[1] For example, 7:01 p. m. eastern standard time would be entered as 1901 e. s. t.; 7:30 a. m. eastern standard time would be entered at 0730 e. s. t.; 6:45 p. m. eastern standard time would be entered as 1845 e. s. t.

§ 83.331 Station records.

In all ship stations authorized to transmit on frequencies within the band 405–535 kHz, a written record shall be maintained of the adjustments of the transmitting and receiving equipment for operation on the assigned frequencies 410 kHz and 500 kHz and at least two authorized working frequencies within this band. This record shall be posted at all times in a conspicuous place on or near the particular equipment involved.

* * * * * *

§ 83.352 Frequencies for use in distress.

(a) The frequency 2182 kHz is the international distress frequency for radiotelephony. It shall be used for this purpose by ship, aircraft, and survival craft stations using frequencies in the authorized bands between 1605 and 4000 kHz when requesting assistance from the maritime services.

(b) The frequency 121.5 MHz (using class A2 emission) is available for radio-beacon purposes to survival craft stations. The frequency 121.5 MHz (using A9 emission) is available to emergency position indicating radiobeacon (EPIRB) stations for facilitating search and rescue operations. The frequency 121.5 MHz (class A3 emission) is available to authorized ship stations for emergency communications between ships and aircraft only if operation on the auxiliary frequency 123.1 MHz is also provided for. The frequency 121.5 is available to authorized ship stations for A3 emission for emergency communications between ships and aircraft involved in coordinated search and rescue operations when other VHF channels are not available. As soon as practicable after establishing contact on 121.5 MHz ships and aircraft engaged in the search and rescue operation should shift to the auxiliary frequency 123.1 MHz. The universal auxiliary frequency 123.1 MHz is available to mobile stations engaged in scene of action search and rescue operations as the auxiliary to the emergency clear channel frequency 121.5 MHz.

(c) The frequency 243 MHz (class A9 emission only) is available to EPIRB stations for facilitating search and rescue operations.

§ 83.353 Frequencies for calling.

(a) The international general radiotelephone calling frequency for the maritime mobile service is 2182 kHz. It may be used as a carrier frequency for this purpose by ship stations and aircraft stations operating in the maritime mobile service:

(1) In addition this frequency may be used for transmission of:

(i) The international urgency signal, and very urgent messages (preceded by this signal) concerning the safety of a ship, aircraft, or other vehicle, or the safety of some person on board or within sight of such ship, aircraft, or vehicle.

(ii) The international safety signal, and messages (preceded by this signal) concerning the safety of navigation or giving important meterological warnings; however, safety messages shall be transmitted, when practicable, on a working frequency after a preliminary announcement on 2182 kHz.

(iii) Brief radio operating signals.

(iv) Brief test signals in accordance with the provisions of § 83.365, as may be necessary to determine whether the radio transmitting equipment of the station is in good working condition on this frequency.

(b) The frequency 156.8 MHz is the international safety and calling frequency for the maritime mobile radiotelephone service in the band 156–174 MHz.

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§ 83.404 Assignable frequencies above 2400 MHz.

(a) The following frequency bands, when designated in the station license, are authorized for use by ship radionavigation stations (including ship radar stations):

2900 to 3100 MHz.
5460 to 5650 MHz.
9300 to 9500 MHz.
14.0 to 14.05 GHz.

The use of the band 5460 to 5650 MHz is limited to shipborne radar.

(b) The following frequency bands, when designated in the station license, are authorized for use by ship radiolocation stations:

(1) 2450 to 2500 MHz, on condition that harmful interference shall not be caused to the fixed and mobile services, and on the condition that no protection shall be given from interference caused by emission from industrial, scientific, or medical equipment;

(2)—

2900 to 3100 MHz.
5460 to 5650 MHz.
9300 to 9500 MHz.

The use of frequencies within these bands for radiolocation shall not cause harmful interference to the radionavigation service and to the Government radiolocation service.

§ 83.405 Special provisions applicable to ship-radar stations.

(a) A ship radar station may be operated under an interim ship station license. The use and operation of a radar station on board ship under the authority conferred by an interim ship station license shall be subject to and in accordance with all applicable rules of the Commission.

(b) Each ship-radar station installation the manufacture of which was completed on or after 1947 shall be furnished with a durable name plate with the manufacturer's name, transmitter model number; and month and year of completion of manufacture permanently inscribed thereon. Such name plate shall be affixed to the indicator housing at the principal radar operating position or to some other component of the radar installation which is readily accessible for inspection.

(c) Each ship-radar station license issued shall be subject to the condition that the station licensee, in relation to the proper operation of the station in accordance with radio law, and rules and regulations of the Commission, will be represented on board the radar-equipped vessel by the person who at any given time occupies the position of master.

(d) The following provisions shall apply to ship-radar stations:

(1) The station licensee of each ship-radar station shall provide and require to be kept at the station a permanent installation and maintenance record. Entries in this record shall be made by or under the personal direction of the responsible installation, service, or maintenance operator concerned in each particular instance, but the station licensee shall have joint responsibility with the responsible operator concerned

for the faithful and accurate making of such entries as are required by this paragraph.

(2) Each entry in this record shall be personally signed by the responsible operator concerned.

(3) The following entries shall be made in this record:

(i) The date and place of initial installation.

(ii) Any necessary steps taken to remedy any interference found to exist at the time of such installation.

(iii) The nature of any complaint (including interference to radio communication) arising subsequent to initial installation, and the date thereof.

(iv) The reason for the trouble leading to the complaint, including the name of any component or component part which failed or was misadjusted.

(v) Remedial measures taken, and date thereof.

(vi) The name, license number, and date of the ship-radar operator endorsement on the first or second class radio operator license of the responsible operator performing or immediately supervising the installation, servicing, or maintenance.

(e) [Reserved]

(f) In addition to the installation and maintenance record required by paragraph (d) of this section, the following documents shall be available for reference on board each radar-equipped vessel:

(1) Part 83 of this chapter.

(2) At least one set of instructions from the respective manufacturer relative to the use and operation of the particular type of ship-radar installation.

(g) No provisions of this part shall require any ship-radar station to transmit any signal(s) intended solely for the purpose of identifying that station.

* * * * * *

Radiotelegraph Stations Provided for Compliance With Part II of Title III of the Communications Act or the Radio Provisions of the Safety Convention

§83.441 Inspection of station.

(a) Every ship of the United States subject to part II of title III of the Communications Act and/or the radio provisions of the Safety Convention shall have the equipment and apparatus prescribed therein inspected at least once every 12 months. The issuance of an appropriate certificate (see section 361 of the Communications Act) in behalf of any vessel of the United States concerning the radio particulars provided for in the Safety Convention is subject to a finding by the Commission that such vessel complies with the applicable radio provisions of that Convention. The issuance date of Cargo Ship Safety Radiotelegraphy Certificates and Cargo Ship Safety Radiotelephony Certificates issued by the Commission shall be the date the station is found to be in compliance or not later than one business day following such incompliance date.

(b) Every ship of the United States holding a Safety Convention certificate is subject when in a port of a foreign country which is a party to the Safety Convention to control by officers duly authorized by the government of that country, insofar as that control is directed towards verifying that there is on board a valid Safety Convention certificate and, if necessary, that the condition of the ship or of its equipment corresponds substantially with the particulars of that certificate.

(c) The privileges of the Safety Convention may not be claimed in favor of any ship unless it holds appropriate valid Convention certificates. In the event of control giving rise to intervention of any kind in a foreign port, the officer carrying out the control is required to notify the United States Consul in writing forthwith of all the circumstances in which intervention was deemed to be necessary.

(d) Certificates issued under and in accordance with the Safety Convention shall be posted in a prominent and accessible place in the ship.

§ 83.442 Radiotelegraph station.

The radiotelegraph station required to be provided on a ship by reason of the provisions of part II of title III of the Communications Act, or on a U.S. ship by reason of the Safety Convention, shall comply in an efficient manner with the provisions of this subpart in addition to all other applicable requirements of this part. The radiotelegraph station comprises a main installation and a reserve installation, electrically separate and electrically independent of each other (except as otherwise provided in paragraph (b) of § 83.443) and such other equipment as may be necessary for the proper use and operation of these installations.

§ 83.443 Main and reserve installations.

(a) The main installation includes a main transmitter, a main receiver, a main power supply, and a main antenna system.

(b) The reserve installation includes a reserve transmitter, a reserve receiver, a reserve power supply, emergency electric lights, and a reserve antenna system: *Provided, however,* That:

(1) *Cargo ships engaged on international voyages.* In installations on cargo ships of 300 gross tons and upwards but less than 1,600 gross tons, and in installations on cargo ships of 1,600 gross tons and upwards installed prior to November 19, 1952, if the main transmitter complies with all the requirements for the reserve transmitter, the latter may be omitted.

(2) *Cargo ships not engaged on international voyages.* In installations on cargo ships of 500 gross tons and upward but less than 1,600 gross tons, and in installations on cargo ships of 1,600 gross tons and upward installed prior to August 13, 1955, if the main transmitter complies with all the requirements for the reserve transmitter, the latter may be omitted.

(3) A cargo ship the keel of which was laid prior to June 1, 1954, may either be equipped with a reserve antenna or provided with a spare antenna consisting of a single-wire transmitting antenna (including suitable insulators) completely assembled for immediate installation.

§ 83.444 Requirements of main installation.

All main radiotelegraph installations shall comply with the following conditions, in addition to all other requirements:

(a) The main antenna shall be as efficient as is practicable and shall be installed and protected so as to insure proper operation of the station. If the main antenna is suspended between masts or other supports liable to whipping, an approved device (safety link) which, under heavy stress, will operate to greatly reduce such stress without breakage of the antenna, the halyards, or any other antenna-supporting elements, shall be installed.

(b) The main transmitter shall be capable of meeting the requirements of § 83.552.

(c) The main receiver shall be capable of efficiently receiving A1 and A2 emission on all frequencies within

the bands 100–200 kHz and 405–535 kHz, and B emission within the band 485–515 kHz. It shall be fitted with headphones capable of effective operation. Where a loudspeaker is additionally provided for use in accordance with the provisions of § 83.204, such device shall also be capable of effective operation. The main receiver shall have sufficient sensitivity to effectively operate headphones or a loudspeaker when the receiver input is as low as 50 microvolts.

(d) There shall be readily available for use under normal load conditions, at all times when required including times of inspection of the ship radio station by a Commission representative, a main power supply for the main installation sufficient to simultaneously (1) energize the main transmitter at its required antenna power, and the main receiver, (2) charge at any required rate all storage batteries forming part of the radiotelegraph station, and (3) charge at any required rate all other storage batteries which are connected to the main power supply for this purpose. Under this load condition the potential of the main power supply at the radio room terminals shall not deviate from its rated potential by more than 10 percent on vessels completed on or after July 1, 1941, nor by more than 15 percent on vessels completed before that date. While at sea, storage batteries forming part of the main installation shall be brought up to the normal fully charged condition daily.

(e) For the purpose of determining the potential (s) of the main power supply at its radio room terminals, a suitable voltmeter or voltmeters of standard accuracy and reliability shall be permanently installed in the radiotelegraph operating room.

(f) The main installation shall be provided with a device permitting changeover from transmission to reception and vice versa without manual switching.

(g) The main installation shall be capable of being quickly connected with and tuned to the main antenna, and the reserve antenna if one is installed.

§ 83.446 Requirements of reserve installation.

(a) All reserve radiotelegraph installations shall comply with the following conditions, in addition to all other requirements:

(1) The reserve installation shall be capable of being placed in operation within a maximum time of 1 minute after the need arises for its use.

(2) The reserve antenna shall be as efficient as is practicable and shall be adequately installed and protected so as to insure proper operation in time of an emergency.

(3) The reserve transmitter shall be capable of meeting the requirements of § 83.553.

(4) The reserve receiver shall be capable of efficiently receiving A1 and A2 emission on all frequencies within the band 405–535 kHz, and B emission within the band 485–515 kHz. It shall be fitted with headphones capable of effective operation. Where a loudspeaker is additionally provided for use in accordance with the provisions of § 83.204, such device also shall be capable of effective operation. The reserve receiver shall have sufficient sensitivity to effectively operate headphones or a loudspeaker when the receiver input is as low as 100 microvolts.

(5) The reserve installation shall be capable of being quickly connected with and tuned to the main antenna, and the reserve antenna if one is installed.

(6) Emergency electric lights shall be provided of not less than 10 watts per unit, capable of being energized solely by the reserve power supply and connected thereto through individual fuses. The emergency electric lights shall be arranged so as to provide satisfactory illumination of the operating controls of the main and reserve radiotelegraph installations and of the radio station clock. The emergency lighting electrical circuits shall be arranged so as to avoid the application of excessive voltage to the emergency lights during the charging of any batteries forming part of the reserve installation. The provisions of this subparagraph shall not preclude the use of any other power supply for energizing these lights solely as an additional provision. If a separate emergency radiotelegraph operating room is provided, the requirements of this subparagraph shall apply to it.

(7) The emergency electric lights shall be controlled by two-way switches placed near the main entrance to the radiotelegraph operating room and at the radiotelegraph operating position, in all cases where the distance between these points is greater than 8 feet: *Provided*, That this requirement shall be applicable to stations when the main or reserve radiotelegraph transmitter is replaced or initially installed in such station on and after May 26, 1965.

(8) There shall be readily available for use under normal load conditions, at all times when required including times of inspection of the ship radio station by a Commission representative, a reserve power supply for the reserve installation which shall be independent of the propelling power of the ship and of any other electrical system and shall be sufficient to simultaneously energize the reserve transmitter at its required antenna power and the reserve receiver for at least 6 hours continuously under normal working conditions, and of energizing the automatic radiotelegraph alarm signal keyer continuously for a period of 1 hour.

(9) The reserve power supply shall be used to energize the reserve installation and the automatic radiotelegraph alarm signal keyer, and may be used to energize the audible warning apparatus included as a component of an approved radiotelegraph auto alarm.

(10) The reserve power supply shall be located as near to the reserve transmitter and reserve receiver as is practicable: *Provided*, That the location of such power supply complies with all applicable rules and regulations of the United States Coast Guard. The switchboard of the reserve power supply shall, wherever possible, be situated in the radiotelegraph operating room; if it is not, it shall be capable of being illuminated.

(11) All reserve power supply circuits shall be appropriately protected from overloads or short circuits which could damage any component thereof.

(12) Means shall be provided for adequately charging any storage batteries forming part of the reserve installation, and such batteries shall be brought to their normal fully charged condition daily while at sea. There shall be provided a device which, during charging of the batteries, will give a continuous indication of the rate and polarity of the charging current.

(13) The cooling system of each internal combustion engine used as a part of the reserve power supply shall be adequately protected or treated to prevent freezing or overheating consistent with the season and route to be traveled by the particular vessel involved.

(b) (1) The shipowner, operating company, or sta-

tion licensee, if directed by the Commission or its authorized representative shall prove by demonstration prescribed in subparagraphs (2), (3), (4), and (5) of this paragraph or by such other means as may be deemed necessary, that the reserve installation satisfies the 6-hour operating requirement of law.

(2) When the reserve power supply, on board a vessel required by law to be equipped with a radiotelegraph station, consists of or includes a storage battery, proof of the ability of such battery to operate continuously and effectively over the 6-hour period of time is authorized to be established by a discharge test over a prescribed period of time, when supplying power at the voltage required for normal and effective operation to an electrical load as prescribed by subparagraph (4) of this paragraph.

(3) When the reserve power supply on board a vessel required by law to be equipped with a radiotelegraph station, consists of or includes an engine-driven generator, proof of the adequacy of the engine fuel supply to operate the unit continuously and effectively over the 6-hour period of time may be established by using as a basis the fuel consumption during a continuous period of 1 hour when supplying power, at the voltage required for normal and effective operation, to an electrical load as prescribed by subparagraph (4) of this paragraph.

(4) For the purpose of determining the electrical load to be supplied by the reserve power supply, the following formula shall be used:

(i) One-half of the reserve transmitter current consumption with the key closed (mark); plus

(ii) One-half of the reserve transmitter current consumption with the key open (space); plus

(iii) One-sixth of the current consumption of the automatic radiotelegraph alarm signal keyer when this device is properly energized; plus

(iv) Current consumption of the reserve receiver; plus

(v) Current consumption of emergency lights.

(5) At the conclusion of the tests specified in subparagraphs (2) and (3) of this paragraph, no part of the reserve power supply shall have an excessive temperature rise, nor shall the specific gravity or voltage of the storage battery be below the 90 percent discharge point as determined from information (such as voltage curves or specific gravity tables) supplied by the manufacturer for the type of battery involved.

§ 83.447 Routing of power supply wiring.

The conductors connecting the main power supply to the main installation, and the conductors connecting the reserve power supply to the reserve installation, shall be so routed as to ensure adequate protection from mechanical injury, shall be protected from overload, and shall be kept clear of electrical grounds.

§ 83.448 Use of reserve installation.

The reserve transmitter, and the reserve power supply for the reserve transmitter, are primarily authorized to be used only for safety and test communication: *Provided*, That this equipment may be used for other communication for a period not to exceed 1 hour per day in the aggregate. The reserve receiver, and the reserve power supply for the reserve receiver if a storage battery, may be used at any time to maintain a watch for safety purposes if such use will not reduce the ability of such reserve power supply to energize the associated component or components of the reserve installation for at least 6 consecutive hours.

§ 83.449 Tests of reserve installation and automatic radiotelegraph alarm signal keyer.

(a) The condition of the reserve installation and of the automatic radiotelegraph alarm signal keyer shall be determined (with the exception noted in paragraph (b) of this section) prior to the vessel's departure from each port and on each day the vessel is outside of a harbor or port: *Provided*, That in the case where the vessel is in two or more ports within 1 day, the required tests need be made only once during such day: *Provide further*, That in the case where the vessel is in a port for less than 1 day, the required tests for that day may be made either prior to the vessel's arrival in that port or prior to the vessel's departure from that port. When the ship is in a foreign port, transmitter tests are subject to such limitations as may be imposed by the Administration having jurisdiction. The following tests shall be made and the results entered in the radiotelegraph station log:

(1) Check the reserve power supply as follows:

(i) Test battery charging circuits for correct polarity and charging rate;

(ii) In the case of lead-acid batteries, determine the specific gravity of the electrolyte of a pilot cell and such other cells as may be necessary to determine the state of charge;

(iii) In the case of other types of batteries, take voltage readings under normal battery load of a pilot cell and such other cells as may be necessary to determine the state of charge;

(iv) When an engine-driven generator is used, check the quantity of fuel in the engine fuel tank;

(2) Test the emergency lighting circuits and emergency electric lights by actual operation;

(3) Determine the proper functioning of the reserve receiver, while energized by the reserve power supply, by actual operation and comparison of received signals with similar signals received by means of the main receiver;

(4) Test the reserve transmitter, while energized by the reserve power supply, by actual operation when connected to the main antenna and to the reserve antenna, if one is installed, noting antenna currents;

(5) Test the automatic radiotelegraph alarm signal keyer for correct timing adjustment of keying mechanism, taking precaution to ensure that any radiotelegraph transmitter to which this device is connected is not energized, in order to preclude actual transmission of alarm signals.

(b) In the case of vessels loading or discharging inflammable or unstable and dangerous cargo, or while berthed at oil terminals or in other comparable areas, it is recognized that predeparture transmitter tests may not safely be made. Accordingly, in all such cases the provisions of paragraph (a)(4) of this section, in connection with predeparture tests, are waived; *Provided*, That suitable explanation is entered in the radio station log.

§ 83.451 Automatic radiotelegraph alarm signal keyer.

The radiotelegraph station required to be provided on a ship of the United States by reason of the provisions of part II of title III of the Communications Act shall include one or more devices, of a type approved by the Commission in accordance with § 83.555, capable of automatically operating the normal keying circuits of a required radiotelegraph transmitter as specified by

§ 83.452 so as to transmit the international radiotelegraph alarm signal.

§ 83.452 Installation of automatic radiotelegraph alarm signal keyer.

(a) The automatic radiotelegraph alarm signal keyer required by § 83.451 shall be installed in a readily accessible place in the radiotelegraph operating room. Means shall be provided in the radiotelegraph operating room to permit instant use of this device to key, non-simultaneously, the main transmitter and the reserve transmitter, and to permit the device to be taken out of operation at any time in order to permit immediate manual transmitter operation. When, pursuant to § 83.442, one transmitter is employed as both a main and reserve transmitter, the automatic radiotelegraph alarm signal keyer shall only be required to be capable of keying this transmitter. Only one control shall be provided for each automatic radiotelegraph alarm signal keyer; this control shall be located in the radiotelegraph operating room.

(b) The required automatic radiotelegraph alarm signal keyer shall be capable of operating efficiently for a continuous period of at least 1 hour when energized solely by the reserve power supply.

§ 83.453 Radiotelegraph auto alarm.

(a) A radiotelegraph auto alarm which is installed and used on board a cargo ship of the United States pursuant to the provisions of § 83.205 comprises a complete receiving, selecting, and warning device of a type approved by the Commission in accordance with section 3(x) of the Communications Act, capable of being actuated automatically by intercepted radio frequency waves forming the international radiotelegraph alarm signal.

(b) The following radiotelegraph auto alarms are acceptable for use pursuant to § 83.205:

(1) A radiotelegraph auto alarm that was type approved by the Commission prior to January 1, 1954, and installed prior to May 26, 1965, is acceptable until May 26, 1969. All radiotelegraph auto alarm type approvals dated prior to January 1, 1954, are canceled as of May 26, 1969.

(2) A radiotelegraph auto alarm that was type approved by the Commission subsequent to January 1, 1954, pursuant to § 83.554.

§ 83.454 Installation of radiotelegraph auto alarm.

(a) A vessel shall be considered as fitted with a radiotelegraph auto alarm pursuant to § 83.453 when the installation on board such vessel complies with the conditions prescribed in the following paragraphs of this section.

(b) The radiotelegraph auto alarm shall be located in the radiotelegraph operating room and shall be installed and protected so as to insure proper operation. Means shall be provided in the radiotelegraph operating room for placing the entire radiotelegraph auto alarm system in or out of operation. A changeover switch shall be provided to: (1) Disconnect the main antenna from all other equipment and connect it to the radiotelegraph auto alarm receiver and place the system in effective operating condition; and, conversely, (2) deenergize the system and reconnect the main antenna to other equipment. A suitable voltmeter shall be provided for the purpose of determining that the supply voltages are within the limits required for proper operation of the system.

(c) Approved apparatus shall be provided for giving an audible warning in the radiotelegraph operating room, in the radio officer's cabin, and on the navigating bridge. This apparatus shall operate continuously after the radiotelegraph auto alarm has been actuated by a radiotelegraph alarm signal or by failure of the system, until manually stopped. Only one switch for stopping the audible warning apparatus from functioning is authorized, and this shall be located in the radiotelegraph operating room and shall be capable of manual operation only.

(d) Failure of the radiotelegraph auto alarm (if of a type approved prior to July 23, 1951) to function normally because of prolonged atmospherics (static) or other prolonged interference, or both, shall operate a visual indicator on the bridge. The type and method of installation of such visual indicator shall comply with the requirements of the United States Coast Guard.

(e) When a radiotelegraph auto alarm is dependent for effective operation upon a power supply having a voltage within definite upper and lower limits, it shall be fitted with an auxiliary device which: (1) will energize the audible warning apparatus if and when this power supply fails or its voltage exceeds the limits specified by the Commission for the particular type of radiotelegraph auto alarm involved; or (2) will automatically connect the radiotelegraph auto alarm to an auxiliary power supply, the voltage of which is within the specified limits.

§ 83.456 Radiotelegraph auto alarm instructions.

There shall be furnished at least two sets of written instructions for the guidance of the radio officer and ship's officers relative to the radiotelegraph auto alarm, which shall include:

(a) A general technical description of the radiotelegraph auto alarm, including a circuit diagram of its receiver, a wiring diagram of its complete installation on shipboard, and a general explanation of its principles of operation;

(b) A list of faults which may be indicated by the sounding of the audible warning apparatus;

(c) An explanation of how to correct faults, remove and replace defective parts, and perform limited repairs at sea;

(d) An explanation of how to test the radiotelegraph auto alarm which shall be summarized upon a card and permanently attached to the front of the radiotelegraph auto alarm in a conspicuous position;

(e) A description of procedure to be followed with respect to adjustments to be made by the radio officer when the audible warning apparatus sounds, and also in making log entries.

§ 83.457 Tests of radiotelegraph auto alarm.

(a) The radio officer shall, at least once every 24 hours while the ship is in the open sea outside of a harbor or port:

(1) Test the efficiency of the radiotelegraph auto alarm by using the testing device to determine whether the apparatus will respond to not less than 4 nor more than 12 consecutive dashes having an approximate duration of 4 seconds and approximate spacing between dashes of 1 second, the timing to be made by reference to the seconds hand of the radiotelegraph station clock;

(2) Determine the proper functioning of the radiotelegraph auto alarm receiver while connected to its

normal antenna, by actual operation and comparison of received signals with similar signals received on 500 kHz by means of the main receiver.

(b) If the radiotelegraph auto alarm is not in proper operating condition, the radio officer shall report that fact to the master or officer on watch on the bridge.

(c) A statement that the tests specified in this section have been made, and entry of the results of such tests, shall be inserted daily in the radiotelegraph station log.

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§ 83.464 Auxiliary receiving antenna.

An effective auxiliary receiving antenna or other approved arrangement shall be provided whenever necessary to avoid unauthorized interruption or reduced efficiency of the required watch by reason of unavailability of the normal receiving antenna for use during the period of time when a radio direction finder on board the vessel is being operated.

§ 83.466 Interior communication systems.

(a) An efficient interior communication system shall be provided between the bridge of the ship and the radiotelegraph operating room in all cases where the radiotelegraph operating room does not adjoin or open onto the navigating bridge structure. An efficient interior communication system shall also be provided between the bridge and the location of the radio direction finding apparatus whenever the latter is not located on the bridge or within any compartment adjoining or opening onto the navigating bridge structure. When the operating position of the reserve radio installation is not located in the radiotelegraph operating room normally used for operating the main radio installation, an efficient interior communication system shall be separately provided between the bridge and each of these radio operating positions.

(b) If a vessel is provided with more than one location from which it is normally controlled and steered, the interior communication system between the radiotelegraph operating room and bridge shall include in the system a point of communication to each such location. The existence at a location of all of the following factors will be considered to be evidence that a point of communication should there be established: (1) Provision of a steering wheel; (2) provision of a compass; (3) provision of an engine order telegraph; (4) provision of apparatus to contol the whistle; and (5) enclosure of the location to form a wheelhouse.

(c) The requirement of paragraph (b) of this section shall not apply to locations established solely for emergency use in event of failure of the normal steering facilities or locations used solely while docking or maneuvering a ship while in port or occasionally for brief periods while navigating the ship in close quarters on inland waters.

§ 83.467 Requirements for interior communication systems.

The interior communication systems required by § 83.466 shall be capable of providing efficient two-way calling and voice communication, shall be independent of any other communication system in the ship, and shall be of a type of system approved by the United States Coast Guard. Further, the location and termination of individual systems shall be subject to approval by the Commission.

§ 83.468 Radiotelegraph station clock.

A reliable clock equipped with a sweep seconds hand and having a dial not less than 5 inches in diameter, the face of which is marked to indicate the silence periods prescribed for the radiotelegraph service by the International Radio Regulations, shall be provided. It shall be securely mounted in the radiotelegraph operating room in such a position that the entire dial can be easily and accurately observed by the radio officer from the normal radiotelegraph operating position, from the operating position at which he would ordinarily transmit the international radiotelegraph alarm signal by hand, and from the position used for testing the radiotelegraph auto alarm (if installed) for response to signals from the testing device. If a separate emergency radiotelegraph operating room is provided, the requirements of this section shall apply to it also.

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§ 83.602 Reports of infringements of the International Radio Regulations.

In the event that infringement of the International Radio Regulations by a foreign station is detected, report thereof may be made by the submission to the Commission of a form similar to that set forth in Appendix 7 to the International Radio Regulations.

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PART 13—COMMERCIAL RADIO OPERATORS

§ 13.1 Licensed operators required.

Unless otherwise specified by the Commission, the actual operation of any radio station for which a station license is required shall be carried on only by a licensed radio operator of the required class (see § 13.61).

NOTE A: Whenever the term "license" is used generally to denote an authorization from the Commission, it includes "license," "permit" and "authorization".

NOTE B: Provision is made in Parts 5, 21, 81, 83, 87, 89, 91, 93, and 95 of this chapter for operation of certain radio stations without licensed operators subject to limitations and conditions specified therein.

§ 13.2 Classification of operator licenses and endorsements.

Commercial radio operator licenses issued by the Commission are classified basically as radiotelegraph and radiotelephone licenses, and are further classified in accordance with international usage. Endorsements are affixed according to special authorizations or restrictions. Licenses and endorsements are designated as follows:

(a) General radio operator group:

(1) General radiotelegraph certificates:

(i) Radiotelegraph First Class Operator License.

(ii) Radiotelegraph Second Class Operator License.
(2) General radiotelephone certificates (classification by international usage):
(i) Radiotelephone First Class Operator License.
(ii) Radiotelephone Second Class Operator License.
(b) Restricted radio operator group:
(1) Special radiotelegraph certificate (classification by international usage):
(i) Radiotelegraph Third Class Operator Permit.
(2) Restricted radiotelephone certificate (classification by international usage):
(i) Radiotelephone Third Class Operator Permit.
(c) Limited radio operator group:
(1) Limited radiotelephone operator certificate:
(i) Restricted Radiotelephone Operator Permit.
(d) License endorsements:
(1) Six months service endorsement—applicable only to radiotelegraph first- and second-class licenses.
(2) Ship radar endorsement—applicable only to radiotelegraph and radiotelephone first- and second-class licenses.
(3) Aircraft radiotelegraph endorsement—applicable only to radiotelegraph first- and second-class licenses.
(4) Broadcasting station operation endorsement—applicable only to radiotelegraph and radiotelephone third-class permits.
(5) Restrictive endorsements as specified in this part of the Rules.

§ 13.3 Dual holding of licenses.

(a) Except as provided by paragraph (b) of this section, a person may not hold more than one radiotelegraph operator license or permit and one radiotelephone operator license or permit at the same time.

(b) A person at the same time may hold both a provisional radiotelephone third class operator permit endorsed for broadcast station operation and either (1) a third class operator permit not endorsed for broadcast station operation, or (2) a restricted radiotelephone operator permit.

§ 13.4 Term of licenses.

(a) Except as provided in paragraphs (b) and (c) of this section, commercial operator licenses will normally be issued for a term of 5 years from the date of issuance.

(b) Restricted Radiotelephone Operator Permits issued to U.S. citizens or other U.S. nationals will normally be issued for the lifetime of the operator. The terms of all Restricted Radiotelephone Operator Permits issued prior to November 15, 1953, which were outstanding on that date were extended to encompass the lifetime of such operators.

(c) A commercial operator license or permit granted to an alien aircraft pilot under a waiver of the U.S. nationality provisions of Section 303(l) of the Communications Act will normally be issued for a term of five (5) years from the date of issuance. An operator license or permit issued to an alien shall be valid only if the operator continues to hold a valid aircraft pilot certificate issued by the Federal Aviation Administration or one of its predecessor agencies.

§ 13.5 Eligibility for new license.

(a) Commercial licenses are issued only to citizens and other nationals of the United States except, in the case of aliens who hold aircraft pilot certificates issued by the Federal Aviation Administration or one of its predecessor agencies, the Commission, if it finds that the public interest will be served thereby, may waive the requirement of United States nationality.

(b) Notwithstanding any other provisions of the Commission's rules, no person otherwise eligible shall be deemed to be eligible to be examined for or to receive a commercial radio operator license of any class, (1) whose commercial radio operator license is under suspension or is involved in a suspension proceeding, (2) who is involved in any pending litigation based on an alleged violation of the Communications Act of 1934, as amended, or (3) who is afflicted with complete deafness or complete muteness or complete inability for any other reason to transmit correctly and to receive correctly by telephone spoken messages in English.

(c) No applicant who is eligible to apply for any commercial radio operator license shall, by reason of any physical handicap, other than as set forth in paragraph (b) of this section, be denied the privilege of applying and being permitted to attempt to prove his qualifications (by examination if examination is required) for such commercial radio operator license in accordance with established procedure; nor, subject to the following conditions, shall such applicant be denied the issuance of any commercial radio operator license for which he is found qualified:

(1) If the applicant is afflicted with uncorrected physical handicap which would clearly prevent the performance of all or any part of the duties of a radio operator, under the license for which application is made, at a station under emergency conditions involving the safety of life or property, he may be issued the license for which he is found qualified: *Provided*, That any license so received, if of the diploma-form (as distinguished from such document of the card-form), shall bear a restrictive endorsement as follows:

> This license is not valid for the performance of any operating duties other than installation, service and maintenance duties, at any station licensed by the Federal Communications Commission which is required, directly or indirectly, by any treaty, statute or rule or regulation pursuant to statute, to be provided for safety purposes.

Provided further, That in the case of a diploma-form license for which no examination in technical radio matters is required, the endorsement will be modified by deleting the reference therein to installation, service and maintenance duties.

(2) If an applicant afflicted with blindness is afforded a waiver of the written examination requirement and is found qualified for a radiotelephone first-class operator license, radiotelephone second-class operator license, and radiotelephone third-class operator permit, and radiotelephone third-class operator permit endorsed for broadcast station operation, he may be issued the license or permit: *Provided*, That the license or permit so received shall bear an endorsement as follows:

> This license is not valid for the operation of any station licensed by the Commission unless the station has been adapted for operation by a blind person and the equipment to be used in such station for that purpose is capable of providing for operation in compliance with the Commission's rules.

(3) In any case where an applicant, who normally would receive or has received a commercial radio operator license bearing the endorsement prescribed by subparagraph (1) of this paragraph, indicates his desire to operate a station falling within the prohibitive terms of the endorsement, he may request in writing that such endorsement not be placed upon, or be removed from, his license, and may submit in support of his request any written comment or statement of himself or any interested party.

(4) An applicant who shows that he has theretofore

performed satisfactorily (by means of the service record appearing on the appropriate license document of the applicant or such other proof as may be appropriate under the circumstances of the particular case) the duties of a radio operator at a station required, directly or indirectly, by any treaty, statute, or rule or regulation pursuant to statute to be provided for safety purposes, during a period when he was afflicted by uncorrected physical handicaps of the same kind and to the same degree as the physical handicaps shown by his current application (this showing may be made by means of the applicant's written, sworn statement or such other documentary proof as may be appropriate under the circumstances of the particular case), shall not be deemed to be within the provisions of subparagraph (1) of this paragraph.

§ 13.6 Operator license, posting of.

The original license of each station operator shall be posted at the place where he is on duty, except as otherwise provided in this part or in the rules governing the class of station concerned.

§ 13.7 Operators, place of duty.

(a) Except as may be provided in the rules governing a particular class of station, one or more licensed radio operators of the grade specified by this part shall be on duty at the place where the transmitting apparatus of each licensed radio station is located and in actual charge thereof whenever it is being operated: *Provided, however,* That (1) subject to the provisions of paragraph (b) of this section, where remote control of the transmitting apparatus has been authorized to be used, the Commission may modify the foregoing requirements upon proper application and showing being made so that such operator or operators may be on duty at the control point in lieu of the place where the transmitting apparatus is located; (2) in the case of two or more stations, except broadcast, licensed in the name of the same person to use frequencies above 30 megahertz only, a licensed radio operator holding a valid radiotelegraph or radiotelephone first- or second-class license who has the station within his effective control may be on duty at any point within the communication range of such stations in lieu of the transmitter location or control point during the actual operation of the transmitting apparatus and shall supervise the emissions of all such stations so as to insure the proper operation in accordance with the station license.

(b) An operator may be on duty at a remote control point in lieu of the location of the transmitting apparatus in accordance with the provisions of paragraph (a) (1) of this section: *Provided,* That all of the following conditions are met: (1) The transmitter shall be so installed and protected that it is not accessible to other than duly authorized persons; (2) the emissions of the transmitter shall be continuously monitored at the control point by a licensed operator of the grade specified for the class of station involved; (3) provision shall be made so that the transmitter can quickly and without delay be placed in an inoperative condition by the operator at the control point in the event there is a deviation from the terms of the station license; (4) the radiation of the transmitter shall be suspended immediately when there is a deviation from the terms of the station license.

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APPLICATIONS

§ 13.11 Procedure.

(a) *General.* Applications shall be governed by applicable rules in force on the date when application is filed (see § 13.28). The application in the prescribed form and including all required subsidiary forms and documents, properly completed and signed, and accompanied by the fee prescribed in the Commission's general fee schedule as set forth in Subpart G, Part 1 of this chapter, shall be submitted to the appropriate office as indicated in paragraph (b) of this section. If the application is for renewal of license, it may be filed at any time during the final year of the license term or during a 1-year period of grace after the date of expiration of the license sought to be renewed. During this 1-year period of grace, an expired license is not valid. A renewed license issued upon the basis of an application filed during the grace period will be dated currently and will not be backdated to the date of expiration of the license being renewed. A renewal application shall be accompanied by the license sought to be renewed. If the prescribed service requirements for renewal without examination (see § 13.28) are fulfilled, the renewed license may be issued by mail. If the service record on the reverse side of the license does not fully describe or cover the service desired by the applicant to be considered in connection with license renewal (as might occur in the case of service rendered at U.S. Government stations), the renewal application shall be supported by documentary evidence describing in detail the service performed and showing that the applicant actually performed such service in a satisfactory manner. A separate application must be submitted for each license involved, whether it requests renewal, new license, endorsement, duplicate, or replacement.

(b) *Place of filing.* (1) An application (FCC Form 753) for restricted radiotelephone operator permit shall be submitted to the Federal Communications Commission, Gettysburg, Pa. 17325, with the following exceptions:

(i) When the applicant is located in Alaska, Hawaii, Puerto Rico, or the Virgin Islands of the United States, the application may be submitted by mail or in person to the nearest engineering field office.

(ii) When the applicant is at any other location and the application is accompanied by a written showing by the applicant of immediate need for a permit for safety purposes and presented in person by the applicant or his agent, the application may be submitted to the nearest engineering field office.

(iii) When the applicant is an alien aircraft pilot (see § 13.4(c)), the application shall be submitted on FCC Form 755 in person or by mail to the Federal Communications Commission, Washington, D.C. 20554.

(2) An application for an operator license or permit of any other class, or for a verification card, shall be submitted in person or by mail to the field office at which the applicant desires his application to be considered and acted upon, and which office will make final arrangements for conducting any required examination. Whenever an examination is required to be taken at a designated examination point away from a field office, the application shall be submitted in advance of the examination to the field office having jurisdiction over the area in which the examination is to be given.

(3) The form entitled "Verification of Operator License or Permit" (FCC 759) may be obtained from any of the Commission's field offices. The certification under Part B of the form shall be completed by the licensee

or general manager of the radio station where the statement is to be posted. When the FCC Form 759 is properly validated, it may be posted in lieu of the original radio operator license or permit when the holder of that license or permit is employed at more than one station.

(c) *Restricted radiotelephone operator permit.* No oral or written examination is required for this permit. If the application is properly completed and signed, and if the applicant is found to be qualified, the permit may be issued forthwith.

(d) *Short term license.* A license or permit issued for a term of less than five years (see § 13.4), may be renewed without further examination, provided proper application is filed in accordance with paragraph (a) of this section.

(e) Blind applicant. A blind person seeking an examination for radiotelephone first-class operator license, radiotelephone second-class operator license, radiotelephone third-class operator license, and radiotelephone third-class operator license with broadcast station operation endorsement shall make a request in writing to the appropriate field office for a time and date to appear for such examination. The examination shall be administered only at the field office. Requests for examinations shall be made at least 2 weeks prior to the date on which the examination is desired.

§ 13.12 Special provisions, radiotelegraph first class.

An applicant for a radiotelegraph first-class operator license must be at least 21 years of age at the time the license is issued and shall have had an aggregate of one year of satisfactory service as an operator manipulating the key of a manually operated public ship or coast station handling public correspondence by radiotelegraphy.

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SCOPE OF AUTHORITY

§ 13.61 Operating authority.

The various classes of commercial radio operator licenses issued by the Commission authorize the holders thereof to operate radio stations, except amateur, as follows (See also § 13.62(c) for additional operating authority with respect to standard and FM broadcast stations):

(a) *Radiotelegraph first-class operator license.* Any station except:

(1) Stations transmitting television, or

(2) Any of the various classes of broadcast stations, or

(3) On a cargo vessel (other than a vessel operated exclusively on the Great Lakes) required by treaty or statute to be equipped with a radiotelegraph installation, the holder of this class of license may not act as chief or sole operator until he has had at least 6 months' satisfactory service in the aggregate as a qualified radiotelegraph operator in a station on board a ship or ships of the United States.

(4) On an aircraft employing radiotelegraphy, the holder of this class of license may not operate the radiotelegraph station during the course of normal rendition of service unless he has satisfactorily completed a supplementary examination qualifying him for that duty, or unless he has served satisfactorily as chief or sole radio operator on an aircraft employing radiotelegraphy prior to February 15, 1950. The supplementary examination shall consist of:

(i) Written examination element: 7.

(5) At a ship radar station, the holder of this class of license may not supervise or be responsible for the performance of any adjustments or tests during or coincident with the installation, servicing or maintenance of the radar equipment while it is radiating energy unless he has satisfactorily completed a supplementary examination qualifying him for that duty and received a ship radar endorsement on his license certifying to that fact: *Provided*, That nothing in this subparagraph shall be construed to prevent persons holding licenses not so endorsed from making replacements of fuses or of receiving-type tubes. The supplementary examination shall consist of:

(i) Written examination element: 8.

(b) *Radiotelegraph second-class operator license.* Any station except:

(1) Stations transmitting television, or

(2) Any of the various classes of broadcast stations, or

(3) On a passenger vessel (a ship shall be considered a passenger ship if it carries or is licensed or certificated to carry more than 12 passengers; a cargo ship means any ship not a passenger ship) required by treaty or statute to maintain a continuous radio watch by operators or on a vessel having continuous hours of service for public correspondence, the holder of this class of license may not act as chief operator, or

(4) On a vessel (other than a vessel operated exclusively on the Great Lakes) required by treaty or statute to be equipped with a radiotelegraph installation, the holder of this class of license may not act as chief or sole operator until he has had at least 6 months' satisfactory service in the aggregate as a qualified radiotelegraph operator in a station on board a ship or ships of the United States.

(5) On an aircraft employing radiotelegraphy, the holder of this class of license may not operate the radiotelegraph station during the course of normal rendition of service unless he is at least eighteen (18) years of age and has satisfactorily completed a supplementary examination qualifying him for that duty, or unless he has served satisfactorily as chief or sole radio operator on an aircraft employing radiotelegraphy prior to February 15, 1950. The supplementary examination shall consist of:

(i) Transmitting and receiving code test at twenty-five (25) words per minute plain language and twenty (20) code groups per minute.

(ii) Written examination element: 7.

(6) At a ship radar station, the holder of this class of license may not supervise or be responsible for the performance of any adjustments or tests during or coincident with the installation, servicing or maintenance of the radar equipment while it is radiating energy unless he has satisfactorily completed a supplementary examination qualifying him for that duty and received a ship radar endorsement on his license certifying to that fact: *Provided*, That nothing in this subparagraph shall be construed to prevent persons holding licenses not so endorsed from making replacements of fuses or of receiving-type tubes. The supplementary examination shall consist of:

(i) Written examination element: 8.

(c) [Reserved].

(d) *Radiotelegraph third-class operator permit.* Any station except:

(1) Stations transmitting television, or

(2) Any of the various classes of broadcast stations, or

(3) Class I–B coast stations (other than when transmitting manual radiotelegraphy for identification or for testing) at which the power in the antenna of the unmodulated carrier wave is authorized to exceed 250 watts, or

(4) Class II–B or Class III–B coast stations (other than those in Alaska and other than when transmitting manual radiotelegraphy for identification or for testing) at which the power in the antenna of the unmodulated carrier wave is authorized to exceed 250 watts, or

(5) Ship stations or aircraft stations other than those at which the installation is used solely for telephony and at which the power in the antenna of the unmodulated carrier wave is not authorized to exceed 250 watts, or

(6) Ship stations and coast stations open to public correspondence by telegraphy, or

(7) Radiotelegraph stations on board a vessel required by treaty or statute to be equipped with a radio installation, or

(8) Aircraft stations while employing radiotelegraphy:

Provided, That (1) such operator is prohibited from making any adjustments that may result in improper transmitter operation, and (2) the equipment is so designed that the stability of the frequencies of the transmitter is maintained by the transmitter itself within the limits of tolerance specified by the station license, and none of the operations necessary to be performed during the course of normal rendition of the service of the station may cause off-frequency operation or result in any unauthorized radiation, and (3) any needed adjustments of the transmitter that may affect the proper operation of the station are regularly made by or under the immediate supervision and responsibility of a person holding a first- or second-class commercial radio operator license, either radiotelephone or radiotelegraph as may be appropriate for the class of station involved (as determined by the scope of the authority of the respective licenses as set forth in paragraphs (a), (b), (e), and (f) of this section and § 13.62), who shall be responsible for the proper functioning of the station equipment, and (4) in the case of ship radio telephone or aircraft radiotelephone stations when the power in the antenna of the unmodulated carrier wave is authorized to exceed 100 watts, any needed adjustments of the transmitter that may affect the proper operation of the station are made only by or under the immediate supervision and responsibility of an operator holding a first- or second-class radiotelegraph license, who shall be responsible for the proper functioning of the station equipment.

(e) *Radiotelephone first-class operator license.* Any station except:

(1) Stations transmitting telegraphy by any type of the Morse code, or

(2) Ship stations licensed to use telephony and power in excess of 100 watts for communication with Class I–B coast stations.

(3) At a ship radar station, the holder of this class of license may not supervise or be responsible for the performance of any adjustments or tests during or coincident with the installation, servicing or maintenance of the radar equipment while it is radiating energy unless he has satisfactorily completed a supplementary examination qualifying him for that duty and received a ship radar endorsement on his license certifying to that fact: *Provided*, That nothing in this subparagraph shall be construed to prevent persons holding licenses not so endorsed from making replacements of fuses or of receiving-type tubes. The supplementary examination shall consist of:

(i) Written examination element: 8.

(f) *Radiotelephone second-class operator license.* Any station except:

(1) Stations transmitting telegraphy by any type of the Morse Code, or

(2) Standard broadcast stations, or

(3) International broadcast stations, or

(4) FM broadcast stations, or

(5) Non-commercial educational FM broadcast stations with transmitter power rating in excess of 1 kilowatt, or

(6) Television broadcast stations, or

(7) Ship stations licensed to use telephony and power in excess of 100 watts for communication with Class I–B coast stations.

(8) At a ship radar station, the holder of this class of license may not supervise or be responsible for the performance of any adjustments or tests during or coincident with the installation, servicing or maintenance of the radar equipment while it is radiating energy unless he has satisfactorily completed a supplementary examination qualifying him for that duty and received a ship radar endorsement on his license certifying to that fact: *Provided*, That nothing in this subparagraph shall be construed to prevent persons holding licenses not so endorsed from making replacements of fuses or of receiving-type tubes. The supplementary examination shall consist of:

(i) Written examination element: 8.

(g) *Radiotelephone third-class operator permit.* Any station except:

(1) Stations transmitting television other than Instructional Television Fixed Service stations, or

(2) Stations transmitting telegraphy by any type of the Morse Code, or

(3) Any of the various classes of broadcast stations, or

(4) Class I–B coast stations at which the power is authorized to exceed 250 watts carrier power or 1,000 watts peak envelope power, or

(5) Class II–B or Class III–B coast stations, other than those in Alaska, at which the power is authorized to exceed 250 watts carrier power or 1,000 watts peak envelope power, or

(6) Ship stations or aircraft stations at which the installation is not used solely for telephony, or at which the power is more than 250 watts carrier power or 1,000 watts peak envelope power:

Provided, That (1) such operator is prohibited from making any adjustments that may result in improper transmitter operation, and (2) the equipment is so designed that the stability of the frequencies of the transmitter is maintained by the transmitter itself within the limits of tolerance specified by the station license, and none of the operations necessary to be performed during the course of normal rendition of the service of the station may cause off-frequency operation or result in any unauthorized radiation, and (3) any needed adjustments of the transmitter that may affect the proper operation of the station are regularly made by or under the immediate supervision and responsibility of a person holding a first- or second-class commercial radio operator license, either radiotelephone or radiotelegraph as may be appropriate for the class of station involved (as determined by the scope of the authority of the respective licenses as set forth in paragraphs (a), (b), (e), and (f)

of this section and § 13.62), who shall be responsible for the proper functioning of the station equipment, and (4) in the case of ship radiotelephone or aircraft radiotelephone stations when the power in the antenna of the unmodulated carrier wave is authorized to exceed 100 watts, any needed adjustments of the transmitter that may affect the proper operation of the station are made only by or under the immediate supervision and responsibility of an operator holding a first- or second-class radiotelegraph license, who shall be responsible for the proper functioning of the station equipment.

(h) *Restricted radiotelephone operator permit.* any station except:

(1) Stations transmitting television, or

(2) Stations transmitting telegraphy by any type of the Morse Code, or

(3) Any of the various classes of broadcast stations other than FM translator and booster stations, or

(4) Ship stations licensed to use telephony for communication with Class I coast stations on frequencies between 4000 kHz and 30 MHz, or

(5) Radio stations provided on board vessels for safety purposes pursuant to statute or treaty, or

(6) Coast stations, other than those in Alaska, while employing a frequency below 30 MHz, or

(7) Coast stations at which the power is authorized to exceed 250 watts carrier power or 1,000 watts peak envelope power;

(8) At a ship radar station the holder of this class of license may not supervise or be responsible for the performance of any adjustments or tests during or coincident with the installation, servicing or maintenance of the radar equipment while it is radiating energy; *Provided*, That nothing in this subparagraph shall be construed to prevent any person holding such a license from making replacements of fuses or of receiving type tubes:

Provided, That, with respect to any station which the holder of this class of license may operate, such operator is prohibited from making any adjustments that may result in improper transmitter operation, and the equipment is so designed that the stability of the frequencies of the transmitter is maintained by the transmitter itself within the limits of tolerance specified by the station license, and none of the operations necessary to be performed during the course of normal rendition of the service of the station may cause off-frequency operation or result in any unauthorized radiation, and any needed adjustments of the transmitter that may affect the proper operation of the station are regularly made by or under the immediate supervision and responsibility of a person holding a first- or second-class commercial radio operator license, either radiotelephone or radiotelegraph, who shall be responsible for the proper functioning of the station equipment.

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§ 13.63 Operator's responsibility.

The licensed operator responsible for the maintenance of a transmitter may permit other persons to adjust a transmitter in his presence for the purpose of carrying out tests or making adjustments requiring specialized knowledge or skill, provided that he shall not be relieved thereby from responsibility for the proper operation of the equipment.

§ 13.64 Obedience to lawful orders.

All licensed radio operators shall obey and carry out the lawful orders of the master or person lawfully in charge of the ship or aircraft on which they are employed.

§ 13.65 Damage to apparatus.

No licensed radio operator shall willfully damage, or cause or permit to be damaged, any radio apparatus or installation in any licensed radio station.

§ 13.66 Unnecessary, unidentified, or superfluous communications.

No licensed radio operator shall transmit unnecessary, unidentified, or superfluous radio communications or signals.

§ 13.67 Obscenity, indecency, profanity.

No licensed radio operator or other person shall transmit communications containing obscene, indecent, or profane words, language, or meaning.

§ 13.68 False signals.

No licensed radio operator shall transmit false or deceptive signals or communications by radio, or any call letter or signal which has not been assigned by proper authority to the radio station he is operating.

§ 13.69 Interference.

No licensed radio operator shall willfully or maliciously interfere with or cause interference to any radio communication or signal.

§ 13.70 Fraudulent licenses.

No licensed radio operator or other person shal alter, duplicate, or fraudulently obtain or attempt t obtain, or assist another to alter, duplicate, or fraudu lently obtain or attempt to obtain an operator license Nor shall any person use a license issued to another or a license that he knows to be altered, duplicated, or fraudulently obtained.

MISCELLANEOUS

§ 13.71 Issue of duplicate or replacement licenses.

(a) If the authorization is of the diploma form, a properly executed application for duplicate should be submitted to the office of issue. If the authorization is of the card form (Restricted Radiotelephone Operator Permit), a properly executed application for replacement should be submitted to the Federal Communications Commission, Gettysburg, Pa., 17325, EXCEPT for alien restricted radiotelephone operator permit applications, which must be submitted to Federal Communications Commission, Washington, D.C. 20554. In either case, the application shall embody a statement of the circumstances involved in the loss, multilation, or destruction of the license or permit. If the authorization has been lost, the applicant must state that reasonable search has been made for it, and further, that in the event it be found, either the original or the duplicate (or replacement) will be returned for cancellation. If the authorization is of the diploma form, the applicant should also submit documentary evidence of the service that has been obtained under the original authorization, or a statement embodying that information.

(b) The holder of any license or permit whose name is legally changed may make application for a replacement document to indicate the new legal name by submitting a properly executed application accompanied by the license or permit affected. If the authorization is of the diploma form, the application should be submitted to the office where it was issued. If the authorization is of the card form (Restricted Radiotelephone Operator Permit) it should be submitted to the

Federal Communications Commission, Gettysburg, Pa. 17325, EXCEPT for alien restricted radiotelephone operator permit applications, which must be submitted to Federal Communications Commission, Washington, D.C. 20554.

§ 13.72 Exhibiting signed copy of application.

When a duplicate or replacement operator license or permit has been requested, or request has been made for renewal, or a request has been made for an endorsement, higher class license or permit, or verification card, the operator shall exhibit in lieu of the original document a signed copy of the application which has been submitted to the Commission.

§ 13.73 Verification card.

The holder of an operator license or permit of the diploma form (as distinguished from such document of the card form) may, by filing a properly executed application accompanied by his license or permit, obtain a verification card (Form 758–F). This card may be carried on the person of the operator in lieu of the original license or permit when operating any station at which posting of an operator license is not required: *Provided*, That the license is readily accessible within a reasonable time for inspection upon demand by an authorized Government representative.

§ 13.74 Posting requirements for operator.

(a) Performing duties other than, or in addition to, service or maintenance, at two or more stations. The holder of any class of radio operator license or permit of the diploma form (as distinguished from the card form) who performs any radio operating duties, as contrasted with but not necessarily exclusive of service or maintenance duties, at two or more stations at which posting of his license or permit is required shall post at one such station his operator license or permit and shall post at all other such stations properly verified posting statements on FCC Form 759.

(b) Performing service or maintenance duties at one or more stations. The holder of a radiotelephone or radiotelegraph first- or second-class radio operator license who performs, or supervises, and is responsible for service or maintenance work on any transmitter of any station for which a station license is required, shall post his license at the transmitter involved whenever the transmitter is in actual operation while service or maintenance work is being performed: *Provided*, That in lieu of posting his license, he may have on his person either his license or a verification card (Form 758–F): *And provided further*, That if he performs operating duties in addition to service or maintenance duties he shall, in lieu of complying with the foregoing provisions of this paragraph, comply with the posting requirements applicable to persons performing such operating duties, as set forth in paragraph (a) of this section, and in the rules and regulations applicable to each service.

§ 13.75 Record of service and maintenance duties performed.

In every case where a station operating log or service and maintenance log is required, the responsible operator in charge of the station operation or maintenance shall make the required entries in the log for the station concerned. If no station log is required, an operator responsible for service or maintenance duties which may affect the proper operation of the station shall sign and date an entry in the station maintenance records giving:

(a) Pertinent details of all service and maintenance work performed by him or under his supervision;

(b) His name and address; and

(c) The class, serial number and expiration date of his license: *Provided*, That the responsible operator shall not be subject to requirements of paragraphs (b) and (c) of this section in relation to a station, or stations of one licensee at a single location, at which he is regularly employed as an operator on a full time basis and at which his license is properly posted.

§ 13.76 Limitation on aircraft pilots.

Notwithstanding any other provisions of this part, an operator permit issued to an alien aircraft pilot pursuant to section 303(1) of the Communications Act shall be valid only for such operation of radio stations on aircraft as is complementary to his functions and duties as a pilot.

Service

§ 13.91 Endorsement of service record.

The licensed operator shall be responsible for obtaining the service record endorsement on the operator license. The endorsement shall include the station call sign(s), types of emission of the station(s) operated, the nature and period of employment, quality of performance of duty, and the signature of the station licencee or his duly authorized agent, or the master of a vessel acting as the agent of the licensee.

§ 13.92 Aviation service endorsement.

If the operator has operated more than three stations in the aviation service, the service may be shown by giving the name of the aviation chain or company in lieu of listing the call letters of the several stations.

§ 13.93 Service acceptability.

Credit will be allowed only for satisfactory service obtained under conditions that required the employment of licensed operators, or when obtained at United States Government stations.

§ 13.94 Statement in lieu of service endorsement.

The holder of a radiotelegraph first- or second-class operator license desiring an endorsement to be placed thereon attesting to an aggregate of at least six months satisfactory service as a qualified operator on a vessel of the United States may, in the event documentary evidence cannot be produced, submit to any field office of the Commission a statement under oath accompanied by the license to be endorsed embodying the following:

(a) Names of ships at which employed;

(b) Call letters of stations;

(c) Types of emission used;

(d) Type of service performed as follows:

(1) Manual radiotelegraph operation only; and

(2) Transmitter control only; or

(3) Combination of (1) and (2) running concurrently;

(e) Whether service was satisfactory or unsatisfactory;

(f) Period of employment;

(g) Name of master, employer, licensee, or his duly authorized agent.

PART 17—CONSTRUCTION, MARKING, AND LIGHTING OF ANTENNA STRUCTURES

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§ 17.47 Inspection of tower lights and associated control equipment.

The licensee of any radio station which has an antenna structure requiring illumination pursuant to the provisions of section 303(q) of the Communications Act of 1934, as amended, as outlined elsewhere in this part:

(a) (1) Shall make an observation of the tower lights at least once each 24 hours either visually or by observing an automatic properly maintained indicator designed to register any failure of such lights, to insure that all such lights are functioning properly as required; or alternatively,

(2) Shall provide and properly maintain an automatic alarm system designed to detect any failure of such lights and to provide indication of such failure to the licensee.

(b) Shall inspect at intervals not to exceed 3 months all automatic or mechanical control devices, indicators, and alarm systems associated with the tower lighting to insure that such apparatus is functioning properly.

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§ 17.49 Recording of tower light inspections in the station record.

The licensee of any radio station which has an antenna structure requiring illumination shall make the following entries in the station record of the inspections required by § 17.47.

(a) The time the tower lights are turned on and off each day if manually controlled.

(b) The time the daily check of proper operation of the tower lights was made, if automatic alarm system is not provided.

(c) In the event of any observed or otherwise known extinguishment or improper functioning of a tower light:

(1) Nature of such extinguishment or improper functioning.

(2) Date and time the extinguishment or improper functioning was observed, or otherwise noted.

(3) Date, time, and nature of the adjustments, repairs, or replacements made.

(4) Identification of Flight Service Station (Federal Aviation Administration) notified of the extinguishment of improper functioning of any code or rotating beacon light or top light not corrected within 30 minutes, and the date and time such notice was given.

(5) Date and time notice was given to the Flight Service Station (Federal Aviation Administration) that the required illumination was resumed.

(d) Upon completion of the periodic inspection required at least once each 3 months:

(1) The date of the inspection and the condition of all tower lights and associated tower lighting control devices, indicators and alarm systems.

(2) Any adjustments, replacements, or repairs made to insure compliance with the lighting requirements and the date such adjustments, replacements or repairs were made.

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APPENDIX III

Abbreviations Available for All Services

Abbreviation	Question	Answer or Advice
QRA	What is the name of your station?	The name of my station is . . .
QRB	How far approximately are you from my station?	The approximate distance between our stations is . . . nautical miles (or . . . kilometers).
QRC	By what private enterprise (or State administration) are the accounts for charges for your station settled?	The accounts for charges of my station are settled by the private enterprise . . . (or State administration).
QRD	Where are you bound and where are you from?	I am bound for . . . from . . .
QRE	What is your estimated time of arrival at . . . (place)?	My estimated time of arrival at . . . (place) is . . . hrs.
QRF	Are you returning to . . . (place)?	I am returning to . . . place or Return to . . . (place).
QRG	Will you tell me my exact frequency (or that of . . .)?	Your exact frequency (or that of . . .) is . . . kHz (or MHz).
QRH	Does my frequency vary?	Your frequency varies.
QRI	How is the tone of my transmission?	The tone of your transmission is . . . (1 Good; 2 Variable; 3. Bad).
QRK	What is the readability of my signals (or those of . . .)?	The readability of your signals (or those of . . .) is . . . (1 Unreadable; 2 Readable now and then; 3 Readable, but with difficulty; 4 Readable; 5 Perfectly readable).
QRL	Are you busy?	I am busy (or I am busy with . . .). Please do not interfere.
QRM	Are you being interfered with?	I am being interfered with.
QRN	Are you troubled by static?	I am troubled by static .

Abbreviation	Question	Answer or Advice
QRO	Shall I increase power?. . .-.	Increase power.
QRP	Shall I decrease power?.	Decrease power.
QRQ	Shall I send faster?.	Send faster (. . . words per minute).
QRR	Are you ready for automatic operation?	I am ready for automatic operation. Send at . . . words per minute.
QRS	Shall I send more slowly?.	Send more slowly (. . . words per minute).
QRT	Shall I stop sending?.	Stop sending.
QRU	Have you anything for me?.	I have nothing for you.
QRV	Are you ready?.	I am ready.
QRW	Shall I inform . . . that you are calling him on . . . kHz (or MHz).	Please inform . . . that I am calling him on . . . kHz (or MHz).
QRX	When will you call me again?.	I will call you again at . . . hours [on . . . kHz (or MHz)].
QRY	What is my turn? (Relates to communication.)	Your turn is No. . . . (or according to any other indication). (Relates to communication.)
QRZ	Who is calling me?.	You are being called by . . . [on kHz (or MHz)].
QSA	What is the strength of my signals (or those of . . .)?	The strength of your signals (or those of . . .) is . . . (1 Scarcely perceptible; 2. Weak; 3 Fairly good; 4 Good; 5 Very good).
QSB	Are my signals fading?.	Your signals are fading.
QSC	Are you a cargo vessel? (See Art. 33 Sec. V).	I am a cargo vessel.
QSD	Is my keying defective?.	Your keying is defective.
QSG	Shall I send . . . telegrams at a time?	Send . . . telegrams at a time.
QSI	. . . . .	I have been unable to break in on your transmission or Will you inform . . . (call sign) that I have been unable to break in on his transmission on [. . . kHz (or MHz)].
QSJ	What is the charge to be collected per word to . . . including your internal telegraph charge?	The charge to be collected per word to . . . including my internal telegraph charge is . . . francs.
QSK	Can you hear me between your signals?	I can hear you between my signals.
QSL	Can you acknowledge receipt?	I am acknowledging receipt.
QSM	Shall I repeat the last telegram which I sent you, or some previous telegram?	Repeat the last telegram which you sent me (or telegram(s) number(s) . . .).
QSN	Did you hear me [or . . . (call sign)] on . . . kHz (or MHz)?	I did hear you [or . . .(call sign)] on . . . MHz (or kHz).
QSO	Can you communicate with . . . direct or by relay?	I can communicate with . . . direct (or by relay through . . .).
QSP	Will you relay to . . . free of charge?	I will relay to . . . free of charge.

Abbreviation	Question	Answer or Advice
QSQ	Have you a doctor on board [or is . . . (name of person) on board]?	I have a doctor on board [or . . . (name of person) is on board].
QSU	Shall I send or reply on this frequency [or on . . . kHz (or MHz)] (with emissions of class . . .)?	Send or reply on this frequency [or on . . . kHz (or MHz)] (with emissions of class . . .).
QSV	Shall I send a series of V's on this frequency [or . . . kHz (or MHz)]?	Send a series of V's on this frequency [or . . . kHz (or MHz)].
QSW	Will you send on this frequency [or . . . kHz (or MHz)] (with emissions of class . . .)?	I am going to send on this frequency [or on . . . kHz (or MHz)] (with emissions of class . . .).
QSX	Will you listen to . . . [call sign(s)] on . . . MHz (or kHz)?	I am listening to . . . [call sign(s)] on . . . kHz (or MHz).
QSY	Shall I change to transmission on another frequency?	Change to transmission on another frequency [or on . . . kHz (or MHz)].
QSZ	Shall I send each word or group more than once?	Send each word or group twice (or . . . times).
QTA	Shall I cancel telegram number . . . as if it had not been sent?	Cancel telegram No. . . . as if it had not been sent.
QTB	Do you agree with my counting of words?	I do not agree with your counting of words; I will repeat the first letter or digit of each word or group.
QTC	How many telegrams have you to send?	I have . . . telegrams for you (or for . . .).
QTE	What is my TRUE bearing from you? or What is my TRUE bearing from . . . (call sign)? What is the TRUE bearing of . . . (call sign) from . . . (call sign)?	Your TRUE bearing from me is . . . degrees (at . . . hours) or Your TRUE bearing from . . . (call sign) was . . . degrees (at . . . hours) or The TRUE bearing of . . . (call sign) from . . . (call sign) was . . . degrees at . . . hours.
QTF	Will you give me the position of my station according to the bearings taken by the direction finding stations which you control?	The position of your station according to the bearings taken by the direction finding stations which I control was . . . latitude . . . longitude, class . . . at . . . hours.
QTG	Will you send two dashes of 10 seconds each followed by your call sign (repeated . . . times) [on . . . kHz (or MHz)]? Will you request . . . to send two dashes of 10 seconds followed by his call sign (repeated . . . times) on . . . kHz (or MHz)?	I am going to send two dashes of 10 seconds each followed by my call sign (repeated . . . times) [on . . . . . kHz (or MHz)] or I have requested . . . to send two dashes of 10 seconds followed by his call sign (repeated . . . times) on . . . kHz (or MHz).
QTH	What is your position in latitude and longitude (or according to any other indication)?	My position is . . . latitude . . . longitude (or according to any other indication).
QTI	What is your TRUE track?	My TRUE track is . . . degrees.
QTJ	What is your speed? (Requests the speed of a ship or aircraft through the water or air, respectively.)	My speed is . . . knots (or kilometers per hour). (Indicates the speed of a ship or aircraft through the water or air, respectively.)

Abbreviation	Question	Answer or Advice
QTK	What is the speed of your aircraft in relation to the surface of the earth?	The speed of my aircraft in relation to the surface of the earth is . . . knots (or kilometers per hour).
QTL	What is your TRUE heading (TRUE course with no wind)?	My TRUE heading is . . .degrees.
QTN	At what time did you depart from . . . (place)?	I departed from . . . (place) at . . . hours.
QTO	Have you left dock (*or port*)? or	I have left dock (or port) or
	Are you airborne?	I am airborne.
QTP	Are you going to enter dock (or port)? or	I am going to enter dock (or port) or
	Are you going to alight (or land)?	I am going to alight (or land).
QTQ	Can you communicate with my station by means of the International Code of Signals?	I am going to communicate with your station by means of the International Code of Signals.
QTR	What is the correct time?	The correct time is . . . hours.
QTS	Will you send your call sign for . . . minute(s) now (or at . . . hours) [on kHz (or MHz)] so that your frequency may be measured?	I will send my call sign for . . . minute(s) now (or at . . . hours) [on . . . kHz (or MHz)] so that my frequency may be measured.
QTU	What are the hours during which your station is open?	My station is open from . . . to . . . hours.
QTV	Shall I stand guard for you on the frequency of . . . kHz (or MHz) from . . . to . . . hours)?	Stand guard for me on the frequency of . . . kHz (or MHz) (from . . . to . . . hours).
QTX	Will you keep your station open for further communication with me until further notice (or until . . . hours)?	I will keep my station open for further communication with you until further notice (or until . . . hours).
QUA	Have you news of . . . (call sign)?	Here is news of . . . (call sign).
QUB	Can you give me, in the following order, information concerning: visibility, height of clouds, direction and velocity of ground wind at . . . (place of observation)?	Here is the information requested . . .
QUC	What is the number (or other indication) of the last message you received from me [or from . . . (call sign)]?	The number (or other indication) of the last message I received from you [or from . . . (call sign)] is . . .
QUD	Have you received the urgency signal sent by . . . (call sign of mobile station)?	I have received the urgency signal sent by . . . (call sign of mobile station) at . . . hours.
QUF	Have you received the distress signal sent by . . . (call sign of mobile station)?	I have received the distress signal sent by . . . (call sign of mobile station) at . . . hours.
QUG	Will you be forced to alight (or land)?	I am forced to alight (or land) immediately. I shall be forced to alight (or land) at . . . (position or place).
QUH	Will you give me the present barometric pressure at sea level?	The present barometric pressure at sea level is . . . (units).

Abbreviation	Question	Answer or Advice
QUI	Are your navigation lights working?	My navigation lights are working.
QUJ	Will you indicate the TRUE course for me to steer toward you (or . . .) with no wind?	The TRUE course for you to steer toward me (or . . .) with no wind is . . .degrees at . . . hours.
QUK	Can you tell me the condition of the sea observed at . . . (place or coordinates)?	The sea at . . . (place or coordinates) is . . .
QUL	Can you tell me the swell observed at . . . (place or coordinates)?	The swell at . . . (place or coordinates) is . . .
QUM	Is the distress traffic ended?	The distress traffic is ended.
QUN	Will vessels in my immediate vicinity [(or in the vicinity of . . . latitude . . . longitude) (or of . . .)] please indicate their position, TRUE course and speed?	My position, TRUE course and speed are . . .
QUO	Shall I search for . . . (1 Aircraft; 2 Ship; 3 Survival craft;) in the vicinity of . . . latitude . . . longitude (or according to any other indication)?	Please search for . . . (1 Aircraft; 2 Ship; 3 Survival craft;) in the vicinity of . . . latitude . . . longitude (or according to any other indication).
QUP	Will you indicate your position by . . . (1 Searchlight; 2 Black smoke trail; 3 Pyrotechnic lights)?	My position is indicated by . . . (1 Searchlight; 2 Black smoke trail; 3 Pyrotechnic lights).
QUQ	Shall I train my searchlight nearly vertical on a cloud, occulting if possible and, if your aircraft is seen, deflect the beam up wind and on the water (or land) to facilitate your landing?	Please train your searchlight on a cloud, occulting if possible and, if my aircraft is seen or heard, deflect the beam up wind and on the water (or land) to facilitate my landing.
QUR	Have survivors . . . (1 Received survival equipment; 2 Been picked up by rescue vessel; 3 Been reached by ground rescue party)?	Survivors . . . (1 Are in possession of survival equipment dropped by . . .; 2 Have been picked up by rescue vessel; 3 Have been reached by ground rescue party).
QUS	Have you sighted survivors or wreckage? If so, in what position?	Have sighted . . . (1 Survivors in water; 2 Survivors on rafts; 3 Wreckage) in position . . . latitude . . . longitude (or according to any other indication).
QUT	Is position of incident marked?	Position of incident is marked (by . . .).

Abbreviation	Question	Answer or Advice
QUU	Shall I home ship or aircraft to my position?	Home ship or aircraft [1 . . . (call sign) to your position by transmitting your call sign and long dashes on . . . kHz (or MHz); 2 . . . (call sign) by transmitting on . . . kHz (or MHz) courses to steer to reach you].
QUV	What is my MAGNETIC bearing from you (or from . . .)? (This signal, in general, will not be used in the Maritime Mobile Service.)	Your MAGNETIC bearing from me (or from . . .) was . . . degrees at . . . hours. (This signal, in general, will not be used in the Maritime Mobile Service.)
QUX	Will you indicate the MAGNETIC course for me to steer toward you (or . . .) with no wind? (This signal, in general, will not be used in the Maritime Mobile Service.)	The MAGNETIC course for you to steer to reach me (or . . .) with no wind was . . . degrees at . . . hours. (This signal, in general, will not be used in the Maritime Mobile Service.)

APPENDIX IV

Miscellaneous Abbreviations and Signals (General)

Abbreviation or Signal	Definition
AA	All after . . . (used after a question mark to request a repetition).
AB	All before . . . (used after a question mark to request a repetition).
ABV	Repeat (or I repeat) the figures in abbreviated form.
ADS	Address (used after a question mark to request a repetition).
AR	End of transmission (.—.—. to be sent as one signal).
AS	Waiting period (.—... to be sent as one signal).
BK	Signal used to interrupt a transmission in progress.
BN	All between . . . and . . . (used after a question mark to request a repetition).
BQ	A reply to an RQ.
C	Yes.
CFM	Confirm (or I confirm).
CL	I am closing my station.
COL	Collate (or I collate).
CP	General call to two or more specified stations.
CQ	General call to all stations.
CS	Call sign (used to request a call sign).
DB	I cannot give you a bearing; you are not in the calibrated sector of this station.
DC	The minimum of your signal is suitable for the bearing.
DE	Used to separate the call sign of the station called from the call sign of the calling station.
DF	Your bearing at . . . (time) was . . . degrees, in the doubtful sector of this station, with a possible error of . . . degrees.
DG	Please advise me if you note an error in the bearing given.
DI	Bearing doubtful in consequence of the bad quality of your signal.
DJ	Bearing doubtful because of interference.
DO	Bearing doubtful. Ask for another bearing later [or at . . . (time)].
DP	Possible error of bearing may amount to . . . degrees.
DS	Adjust your transmitter, the minimum of your signal is too broad.
DT	I cannot furnish you with a bearing; the minimum of your signal is too broad.

Abbreviation or Signal	Definition
DY	This station is not able to determine the sense of the bearing. What is your approximate direction relative to this station?
DZ	Your bearing is reciprocal. (To be used only by the control station of a group of direction-finding stations when it is addressing stations of the same group.)
ER	Here . . .
ETA	Estimated time of arrival.
ITP	The punctuation counts.
JM	Make a series of dashes if I may transmit. Make a series of dots to stop my transmission (not to be used on 500 kHz except in cases of distress).
K	Invitation to transmit
MN	Minute (**or** Minutes).
MSG	Prefix indicating a message to or from the master of a ship concerning its operation or navigation.
N	No.
NIL	I have nothing to send you.
NW	Now.
OK	We agree (**or** It is correct).
P	Prefix indicating a private radiotelegram.
PBL	Preamble (used after a question mark to request a repetition).
PTR	Used by a coast station to request the position and next port of call of a mobile station.
R	Received.
REF	Reference to . . . (**or** Refer to . . .).
RPT	Repeat (**or** I repeat) (**or** Repeat . . .).
RQ	Indication of a request.
SIG	Signature (used after a question mark to request a repetition).
$\overline{\text{SOS}}$	Distress Signal (...———... to be sent as one signal).
SS	Indicator preceding the name of a ship station.
SVC	Prefix indicating a service telegram.
SYS	Refer to your service telegram.
TFC	Traffic.
TR	Used as a prefix to indicate reply to PTR.
TTT	This group when sent three times constitutes the safety signal.
TU	Thank you.
TXT	Text (used after a question mark to request a repetition).
$\overline{\text{VA}}$	End work (...—.— to be sent as one signal).
W	Word(s) **or** [Group(s)].
WA	Word after . . . (Use after a question mark to request a repetition).
WB	Word before . . . (used after a question mark to request a repetition).
XXX	This group when sent three times constitutes the urgency signal.

APPENDIX V

Morse Code Signals

Extracts from the Telegraph Regulations (Paris Revision, 1949) annexed to the International Telecommunication Convention (Atlantic City, 1947):

SPACING AND LENGTH OF SIGNALS

(A) A dash is equal to three dots.
(B) The space between the signals forming the same letter is equal to one dot.
(C) The space between two letters is equal to three dots.
(D) The space between two words is equal to seven dots.

LETTERS

a ·—	i ··	r ·—·
b —···	j ·———	s ···
c —·—·	k —·—	t —
d —··	l ·—··	u ··—
e ·	m ——	v ···—
é ··—··	n —·	w ·——
f ··—·	o ———	x —··—
g ——·	p ·——·	y —·——
h ····	q ——·—	z ——··

FIGURES

1 ·————	6 —····
2 ··———	7 ——···
3 ···——	8 ———··
4 ····—	9 ————·
5 ·····	0 —————

SIGNS

Full stop (period)	[.]	· — · — · —
Comma	[,]	— — · · — —
Colon	[:]	— — — · · ·
Question mark (note of interrogation) or request for repetition of a transmission not understood	[?]	· · — — · ·
Apostrophe	[']	· — — — — ·
Hyphen or dash	[–]	— · · · · —
Fraction bar	[/]	— · · — ·
Brackets (parentheses) (before and after the words)	[()]	— · — — · —
Inverted commas (quotation marks) (before and after the words)	["]	· — · · —

Administrations and recognized private operating agencies using code converters may use the apostrophe twice, before and after the words, to signal inverted commas (quotation marks).

Double hyphen	[=]	— · · —
Understood		· · · — ·
Error		· · · · · · · ·
Cross or signal for the end of a telegram or of transmission		· — · — ·
Invitation to transmit		— · —
Wait		· — · · ·
End of work		· · · — · —
Starting signal (to precede every transmission)		— · — · —

The provisions regarding the transmission of fractional numbers which are applicable to instruments using International Telegraph Alphabet No. 1 shall also be applicable to instruments using the Morse code.

A group consisting of figures and letters shall be transmitted without space between figures and letters.

The following letters and signals may be used in relations between countries which accept them:

ä	· — · —	ñ	— — · — —
á or å	· — — · —	ö	— — — ·
ch	— — — —	ü	· · — —

A number which includes a fraction shall be transmitted with the fraction linked to the whole number by a single hyphen.

Examples: 1-3/4 and not 13/4; 3/4-8 and not 3/48; 363-1/2 4 5642 and not 3631/2 4 5642.

APPENDIX VI

Information Concerning Commercial Radio Operator Licenses and Permits

THE APPLICATION

(1) An applicant must normally be a citizen or national of the United States. Under certain circumstances, U.S. nationality may be waived for:
   1) Alien aircraft pilots,
   2) Citizens of a U.S. Trust Territory.

(2) Except for the Restricted Radiotelephone Operator Permit, submit in advance a completed application Form 756 and appropriate fee to the office which will administer the examination. If the examination is to be taken at an FCC office, the forms may be obtained and completed at the time of the examination. To request a Restricted Radiotelephone Operator Permit for which no examination is required, submit FCC application Form 753 and the fee by mail to the Commission's office at Gettysburg, Pa. 17325.

(3) The Commission has not established any age limit for applicants who wish to obtain commercial radio operator licenses, except that radiotelegraph first-class operator licenses may not be issued to applicants under twenty-one (21) years of age, applicants for examination for an Aircraft Radiotelegraph Endorsement must be at least eighteen (18) years of age, and applicants for the Restricted Radiotelephone Operator Permit must be at least fourteen (14).

(4) Each radio operator application form inquires as to the applicant's criminal record, if any, the status of his citizenship, and his physical ability to perform duties of a radio operator.

EXAMINATIONS

(5) An applicant for a Radiotelegraph license must successfully pass the prescribed code test consisting of both transmitting and receiving the International Morse Code for a period of one minute without error. This test is computed counting 5 letters per word or group with punctuation and numerals counting as 2 letters. It may be written in either pencil or ink. Semiautomatic keys and typewriters may be used for the 25 wpm test if furnished by the applicant. The speed requirements are as follows:

Radiotelegraph Third-Class Operator Permit	16 code groups per minute and 20 words per minute, plain language.
Radiotelegraph Second-Class Operator License	16 code groups per minute and 20 words per minute, plain language.
Radiotelegraph First-Class Operator License	20 code groups per minute and 25 words per minute, plain language.

(6) An applicant must be able to transmit and receive spoken messages in English and successfully pass written examination elements as follows:

Restricted Radiotelephone Operator Permit	No written examination required.
Radiotelephone Third-Class Operator Permit	Elements 1 and 2.
Radiotelephone Second-Class Operator License	Elements 1, 2, and 3.
Radiotelephone First-Class Operator License	Elements 1, 2, 3, and 4.
Radiotelegraph Third-Class Operator Permit	Elements 1, 2, and 5.
Radiotelegraph Second-Class Operator License	Elements 1, 2, 5, and 6.
Radiotelegraph First-Class Operator License	Elements 1, 2, 5, and 6.

The Commission's examination elements consist of the following:

No. 1, Basic Law—Provisions of laws, treaties and regulations with which every operator should be familiar. (20 questions, multiple-choice type)

No. 2, Basic Operating Practice—Operating procedures and practices generally followed or required in communicating by radiotelephone stations. (20 questions, multiple-choice type)

No. 3, Basic Radiotelephone—Technical, legal and other matters applicable to operating radiotelephone stations other than broadcast. (100 questions, multiple-choice type)
No. 4, Advanced Radiotelephone—Advanced technical, legal and other matters particularly applicable to operating various classes of broadcast stations. (50 question, multiple-choice type)
No. 5, Radiotelegraph Operating Practice—Radio operating procedures and practices generally followed or required in communicating by radiotelegraph stations primarily other than in the maritime mobile services of public correspondence. (50 questions, multiple-choice type)
No. 6, Advanced Radiotelegraph—Technical, legal, and other matters applicable to operating all classes of radiotelegraph stations including maritime mobile services of public correspondence, message traffic routing and accounting, radio navigational aids, etc. (100 questions)
No. 7, Aircraft Radiotelegraph—Special endorsement on Radiotelegraph First- and Second-Class Operator Licenses. Theory and practice in operation of radio communication and navigational systems in use on aircraft. (100 questions, multiple-choice type; code test of 20 code groups per minute and 25 wpm plain language.)
No. 8, Ship Radar Techniques—Special endorsement on Radiotelegraph First- or Second-Class Operator Licenses. Specialized theory and practice applicable to proper installation, servicing, and maintenance of ship radar equipment in use for marine navigational purposes. (50 questions, multiple-choice type)
No. 9, Basic Broadcast—Special endorsement on Radiotelephone Third-Class Operator License. Specialized elementary theory and practice in operation of standard (a-m) and fm broadcast stations. (20 questions, multiple-choice type)

(7) Except insofar as the requirement of one-year service for eligibility for a Radiotelegraph First-Class Operator License, as outlined under Item 12 herein, may be considered a training requirement, there are no educational or training requirements set up by the Commission as a prerequisite to taking an examination.

3) Examinations for commercial radio operator licenses are conducted at each radio district office of the Commission on the days designated by the Engineer in Charge of the office. In addition to the radio district offices of the Commission, examinations are held in certain other cities on dates designated by the Engineer in Charge of the radio district in which these cities are located. A list of designated examination points will be forwarded upon request or when necessary to answer inquiries regarding such points. Specific dates and times of examinations should be obtained from the Engineer in Charge of the office concerned in each instance. Available facilities do not permit extension of the

regular radio operator license examination procedure to applicants overseas. It is suggested that applicants overseas arrange for examination when they are able to appear at one of the Commission's designated examination points.

(9) The holder of a license, who applies for another class of license or special endorsement, will be required to pass only the additional written examination elements for the new class of license. Applicants should bring with them and present any licenses, permits and verification cards they may hold to the examiner at the time of examination. If the holder of a license qualifies for a higher class license in the same group, the license held will be submitted for cancellation and returned to the licensee upon issuance of the new license. Since code tests are not considered as "elements," credit for them is not generally allowed, and it is necessary to requalify.

(10) An applicant who fails an examination element will be ineligible for a period of two months to take an examination for any class of license requiring that element. Examination elements will be graded in the order listed (not necessarily the same day completed), and an applicant may, without further application, be issued the class of license or permit for which he qualifies. Seventy-five percent is the passing grade for written examination elements.

(11) Any person who obtains or attempts to obtain, or assists another to obtain or attempt to obtain an operator license or permit by fraudulent means is committing a Federal offense for which se vere penalties may be imposed.

PRIOR EXPERIENCE REQUIRED

(12) An applicant for a radiotelegraph first-class operator license shall have had an aggregate of one year of satisfactory service as an operator manipulating the key of a manually operated public ship or coast station handling public correspondence by radiotelegraphy.

(13) To obtain employment as the sole radio operator on most cargo ships it is required that the licensed operator must have had at least six months prior satisfactory service as a qualified radiotelegraph operator in a station on board a ship or ships of the United States.

FEE SCHEDULE

(14) The following application filing fees must accompany applications for radio operator licenses and permits: $5 for first class, $4

for second class, $3 for third class, and $2 for commercial operator license endorsements, duplicates, renewals, and replacements, and $8 for restricted radiotelephone operator permits. Whenever an applicant requests both an operator license and an endorsement, the required fee will be the fee prescribed for the license document involved. Fees should be paid by check or money order payable to the Federal Communications Commission. If an examination is to be taken at a place away from a field office, the application and fee should be filed in advance at the field office administering the examination.

VERIFICATION OF LICENSE HOLDING

(15) Operators holding a radio operator license of the diploma form (other than Restricted Radiotelephone Operator Permit) may obtain a Verification Card, FCC Form 758-F, attesting to license holding. Verification Cards may be carried on the person of the operator in lieu of the license when operating a station at which the posting of an operator license is not required. When such Verification Cards are used, the original license or permit must be readily accessible for inspection by an authorized government representative.

(16) If an operator is required to post his radio operator license at more than one station, he may post the original license or permit at one station and post Verified Statements, FCC Form 759, at the other stations.

(17) Verification Cards or Verified Statements may be obtained by filing a properly completed application Form 756. The license or permit must accompany the request for verification. In lieu of the license or permit, the operator shall exhibit a signed copy of the application which has been submitted by him until action is taken on the request.

RENEWALS, DUPLICATES, AND REPLACEMENTS

(18) An operator whose license or permit of the diploma form (other than Restricted Radiotelephone Operator Permits) has been lost, mutilated or destroyed, shall immediately notify the Commission. An application Form 756 for a duplicate may be submitted to the office issuing the original license or permit embodying a statement attesting to the facts thereof. A replacement Restricted Radiotelephone Operator Permit may be requested by filing application Form 753 and the required fee with the Commission's Gettysburg, Pa. office.

(19) The holder of any license or permit whose name is legally changed may make application for a replacement document to indicate the new legal name, by submitting a properly completed application and the required fee to the office of original issue, accompanied by the license or permit affected.

(20) Licenses are normally renewable at any time within the last year of the license term or during a one-year period of grace after the date of expiration. During this grace period, an expired license is not valid. At this time it is not necessary to show service under a license sought to be renewed. (Renewal applications, when accompanied by the expiring license, should be filed at the nearest District Office. If the expiring license has been lost, destroyed, or mutilated, the application should be filed at the office which issued the original document. Applications may be by mail and should be submitted through the use of FCC Form 756.)

(21) When a duplicate or replacement operator license or permit has been requested or request has been made for renewal, or for an endorsement, in lieu of the license or permit, the operator shall exhibit a signed copy of the application which has been submitted by him.

GENERAL INFORMATION

(22) All licenses and permits other than amateur are considered to be commercial licenses and permits. Radio operator license requirements are usually governed by the type of emission involved and whether or not the operator's duties include making adjustments to transmitters.

(23) A license is not required for the operation of or repairs to radio or television *receiving* equipment.

(24) The Commission does not issue licenses for radio engineers, television engineers, television comeramen, radio mechanics, radio announcers, or studio console operators. Persons who are employed at these jobs are required to hold operator licenses of the proper type and class issued by the Commission only if their duties include the operation of radio transmitting and/or video transmitting equipment.

(25) Restricted radiotelephone operator permits are normally issued for the lifetime of the holder. Commercial operator licenses and permits of other classes are normally issued for a term of five years from the date of issue.

(26) The minimum requirement of persons wishing to obtain employment as an operator at a standard (a-m) or fm broadcast station is a Radiotelephone Third-Class Operator Permit with the Basic

Broadcast endorsement. (Examination Elements 1, 2, and 9). A nonrenewable Provisional Radio Operator Certificate, which carries with it all the authority now embraced by a Radiotelephone Third-Class Operator Permit endorsed for Broadcast use, may be obtained by mail and without examination. The holder is expected to fulfill the examination requirements within the one year term of the certificate. Application may be made on FCC Form 756-C, which may be obtained from any of the Commission's Field Engineering Offices.

(27) Holders of Restricted Radiotelephone Operator Permits or Radiotelephone and Radiotelegraph Third-Class Operator Permits are in general prohibited from making adjustments that may result in improper transmitter operation. The Commission's Rules require that radio transmitting equipment operated by holders of these operator permits shall be so designed that none of the operations necessary to be performed during the course or normal rendition of service may cause off-frequency operation or result in any unauthorized radiation. Any needed adjustments to transmitters operated by holders of the Restricted Radiotelephone Operator Permit and Radiotelephone and Radiotelegraph Third-Class Operator Permits should be made by or in the presence of the holder of a higher class license of the proper grade.

(28) In general, anyone wishing to obtain employment as an operator at a ship radiotelegraph station should hold a Radiotelegraph First- or Second-Class Operator License. Restricted Radiotelephone Operator Permits are valid for the normal operation of radiotelephone equipment installed in most aircraft, at certain ground stations, and on most boats where radio equipment is not mandatory.

(29) The class of commercial radio operator license which is normally required as sufficient authority to install, service, and maintain radiotelephone transmitting equipment on board aircraft and small boats and most radio transmitting equipment in the land-mobile services is the Radiotelephone Second-Class Operator License. Successful completion of Commercial Examination Elements 1, 2, and 3 is required prior to the issuance of this class of license.

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MARINE RADIOTELEGRAPH OPERATOR LICENSE HANDBOOK

by Edward M. Noll

A person who operates or maintains a marine radiotelegraph station must hold a valid radiotelegraph operator license of the proper class for the station involved. To qualify for such a license, an applicant must pass an examination that includes several written elements in addition to the code test itself. This book has been designed to serve as a helpful guide for preparing to take the written examination.

The first two chapters provide a general coverage of shipboard radio equipment, including transmitters, antennas, alarms, direction finders, loran equipment, and radar sets. These chapters provide the background needed to be able to answer the technical questions on the test.

Chapters 3 through 14 contain hundreds of questions similar to those contained in the license examinations, together with answers to the questions and, where necessary, explanations of the answers. The questions have been grouped according to specific areas of subject matter and arranged for good continuity of study. These 12 chapters cover the information necessary for the written test elements for radiotelegraph licenses. Chapter 15 is included for those who wish to take the additional examination for a radar license endorsement. The question-and-answer chapters are based on the FCC *Study Guide and Reference Material for Commercial Radio Operator Examinations.*

To complement the main part of the book, there are six appendices that contain extracts from radio laws and treaties, extracts from the FCC Rules and Regulations, and other useful information. Illustrations have been used wherever necessary to support the text, and the entire book has been organized for an orderly study of the subject matter. *Marine Radiotelegraph Operator License Handbook* contains all the information you need to pass the written examination for a radiotelegraph license. This book will serve as an invaluable aid and a worthwhile investment for anyone planning a career as a marine radiotelegraph operator.

ABOUT THE AUTHOR

In addition to being an accomplished author of technical books, lessons, articles, and instruction manuals, Ed Noll is also a consulting engineer and lecturer. His other SAMS books include: *Radio Operators License Handbook* (third-class radio telephone with broadcast endorsement); *Second-Class Radiotelephone License Handbook; First-Class Radiotelephone License Handbook; Radar License Endorsement Handbook; Science Projects in Electronics; FET Principles, Experiments, and Projects; Linear IC Principles, Experiments, and Projects,* and *SWL Antenna Construction Projects.*

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